US009147673B2

(12) **United States Patent**
Nishiuchi et al.

(10) **Patent No.: US 9,147,673 B2**
(45) **Date of Patent: Sep. 29, 2015**

(54) **SEMICONDUCTOR POWER CONVERTER AND METHOD OF MANUFACTURING THE SAME**

(71) Applicant: **Kabushiki Kaisha Toshiba**, Tokyo (JP)

(72) Inventors: **Hideo Nishiuchi**, Kuwana (JP); **Kazuhiro Ueda**, Aisai (JP); **Takayuki Masunaga**, Yokkaichi (JP); **Naotake Watanabe**, Mie-gun (JP); **Yoshiyuki Shimizu**, Tokyo (JP); **Takashi Togasaki**, Yokohama (JP); **Koji Maruno**, Yokkaichi (JP)

(73) Assignee: **Kabushiki Kaisha Toshiba**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 12 days.

(21) Appl. No.: **14/025,019**

(22) Filed: **Sep. 12, 2013**

(65) **Prior Publication Data**

US 2014/0117526 A1 May 1, 2014

(30) **Foreign Application Priority Data**

Oct. 31, 2012 (JP) 2012-240990
Jun. 28, 2013 (JP) 2013-137218

(51) **Int. Cl.**
H01L 23/10 (2006.01)
H01L 25/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 25/50*** (2013.01); ***H01L 21/4839*** (2013.01); ***H01L 21/4842*** (2013.01); ***H01L 23/473*** (2013.01); ***H01L 23/49562*** (2013.01); ***H01L 23/50*** (2013.01); ***H01L 25/072*** (2013.01); *H01L 23/3107* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 23/10; H01L 25/00; H01L 23/53; H01L 23/495; H01L 23/051; H01L 23/08
USPC 438/107, 121–127, 214, 280
See application file for complete search history.

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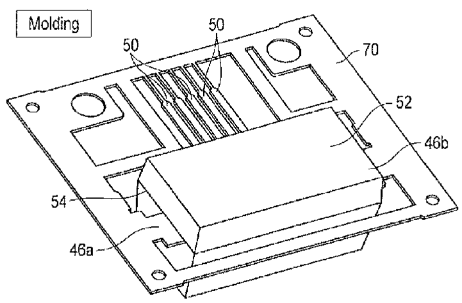
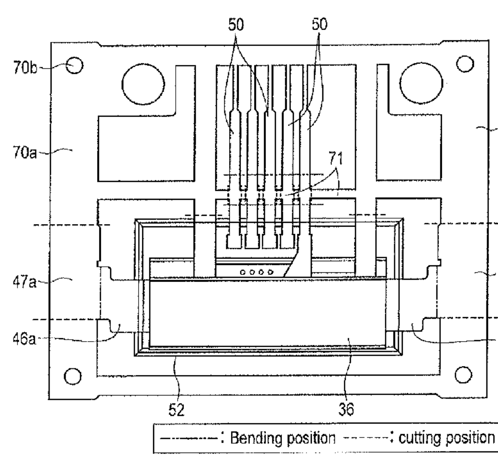
Primary Examiner — Chuong A Luu
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

According to one embodiment, a semiconductor power converter includes first and second electrical conductors opposed to each other, first and second semiconductor elements joined to a first joint surface of the first electrical conductor, first and second convex electrical conductors joined to the first and second semiconductor elements, a junction joined to the first and second convex electrical conductors and a second joint surface of the second electrical conductor, power terminals, signal terminals, and an envelope sealing the constituent members. The envelope includes a flat bottom surface which extends perpendicular to the semiconductor elements and in which first and second bottom surfaces of the electrical conductors are exposed.

8 Claims, 27 Drawing Sheets





(51) **Int. Cl.**

H01L 23/50	(2006.01)
H01L 25/07	(2006.01)
H01L 23/473	(2006.01)
H01L 23/495	(2006.01)
H01L 21/48	(2006.01)
H01L 23/40	(2006.01)
H01L 23/31	(2006.01)

(52) **U.S. Cl.**

CPC .. *H01L 23/4006* (2013.01); *H01L 2224/48247* (2013.01); *H01L 2224/49171* (2013.01); *H01L 2924/1305* (2013.01); *H01L 2924/13055* (2013.01)

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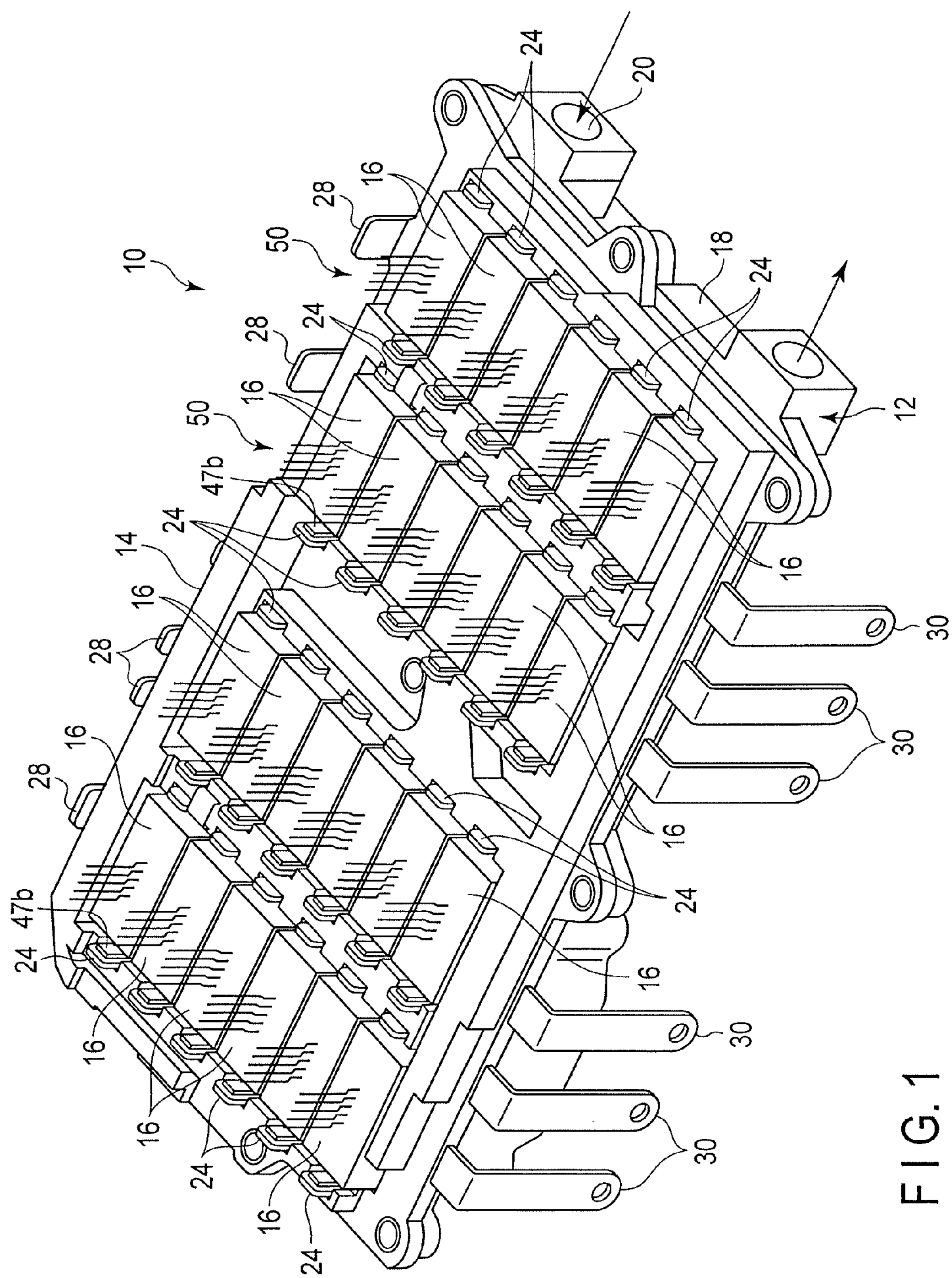
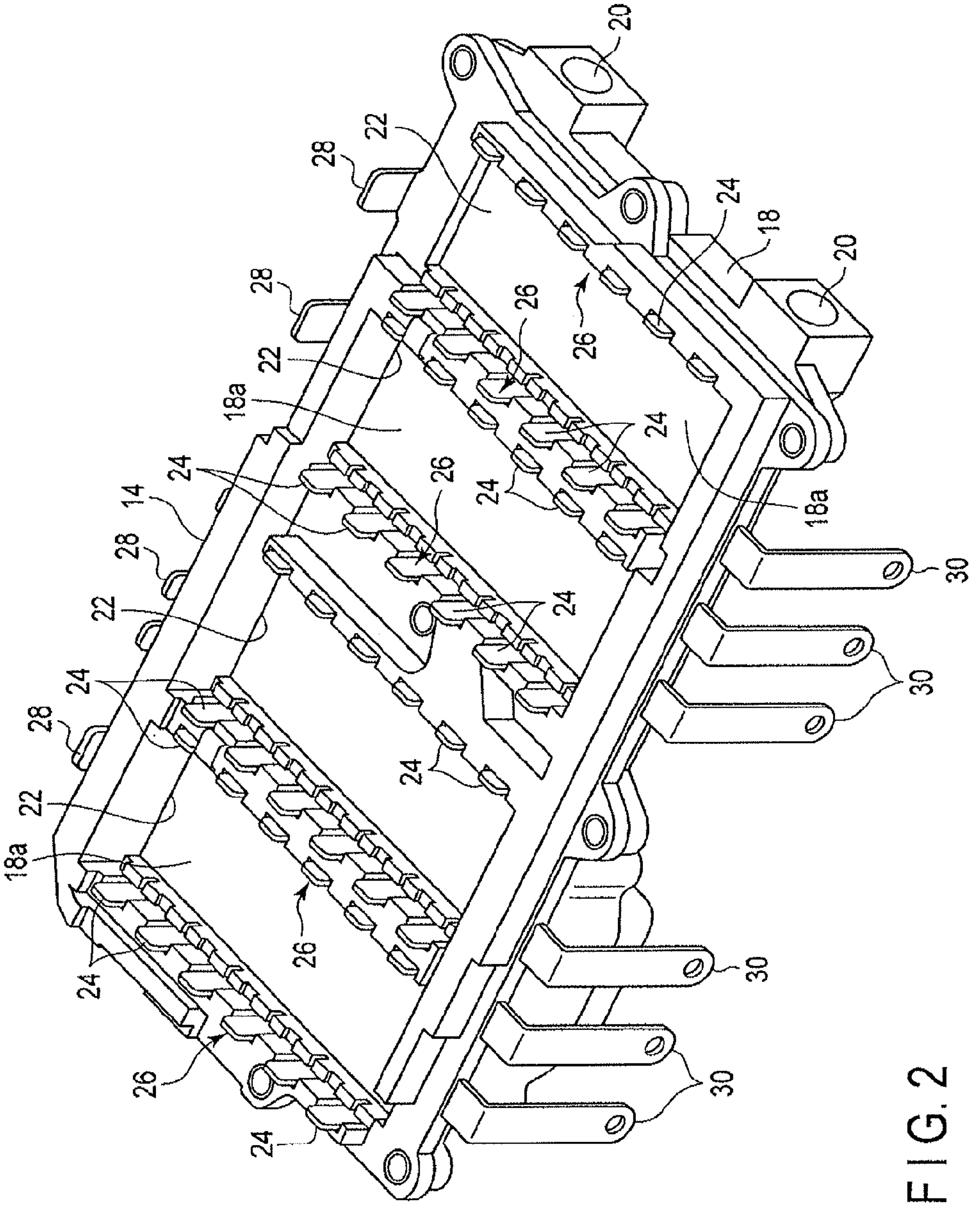


FIG. 1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22
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26
22
18a
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14
26
24
18a
28
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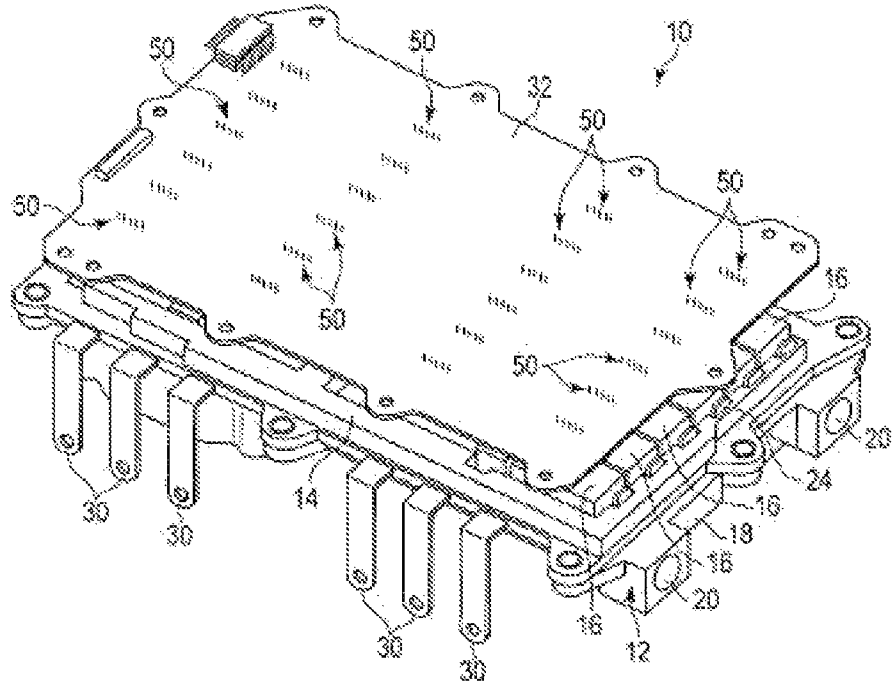
22
24
30
24
28
24
22
18a
26
24
30
26
30
24

FIG. 2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50
32
50
50
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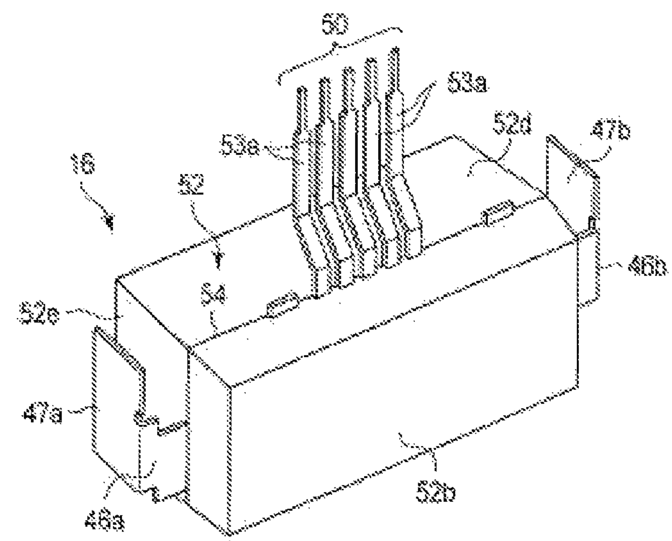
18
16
20
16
12
14
30
30
30
30

FIG. 3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53a
53a
52d
47b
16
52
46b
52e
54
47a
46a
52b

FIG. 4

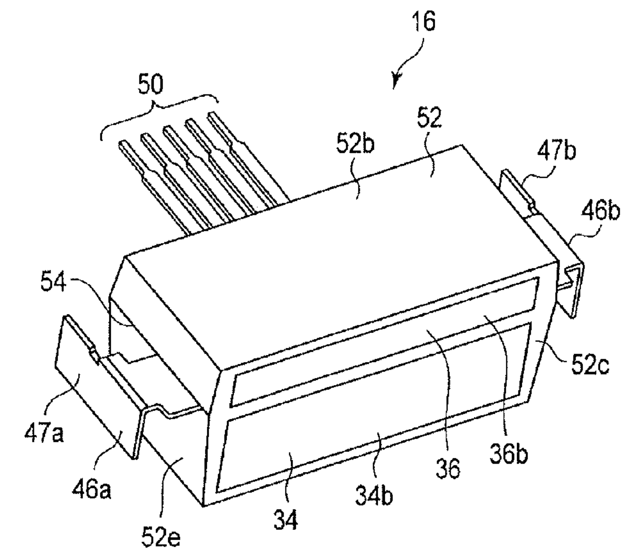

16
50
52b
52
47b
46b
54
52c
47a
46a
52e
34
34b
36
36b

FIG. 5

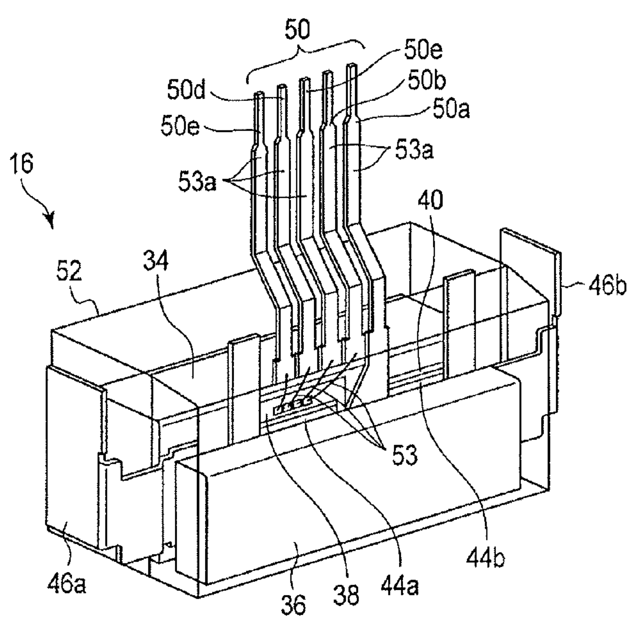
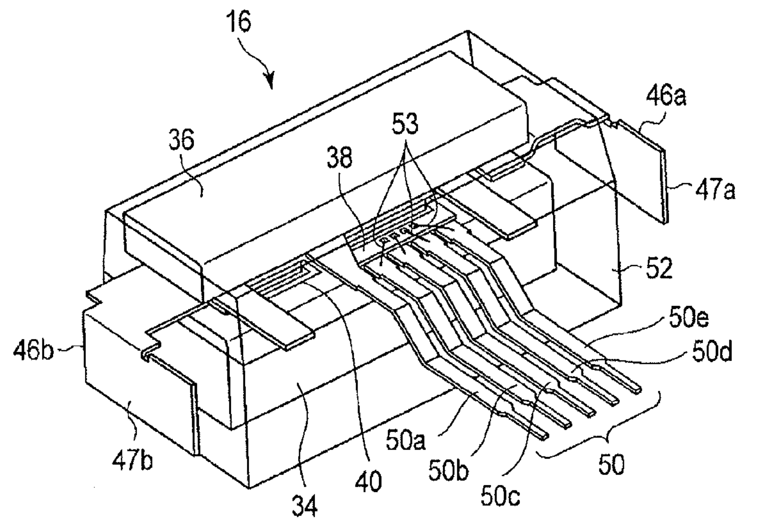
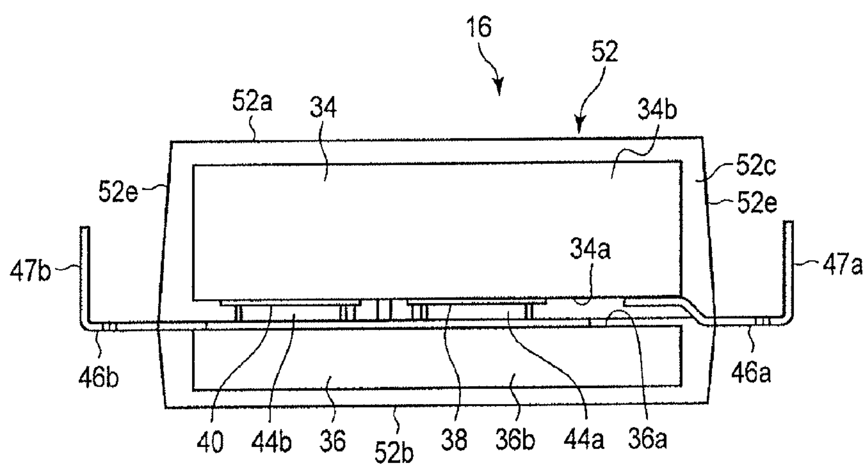

50
50e
50d
50b
50e
50a
53a
53a
16
40
52
34
46b
53
46a
36
38
44a
44b

FIG. 6


16
36
38
53
46a
47a
52
50e
50d
46b
47b
34
40
50a
50b
50c
50

F I G. 7


16
52
52a
34
34b
52c
52e
52e
47b
34a
47a
46b
46a
40
44b
36
52b
38
36b
44a
36a

F I G. 8

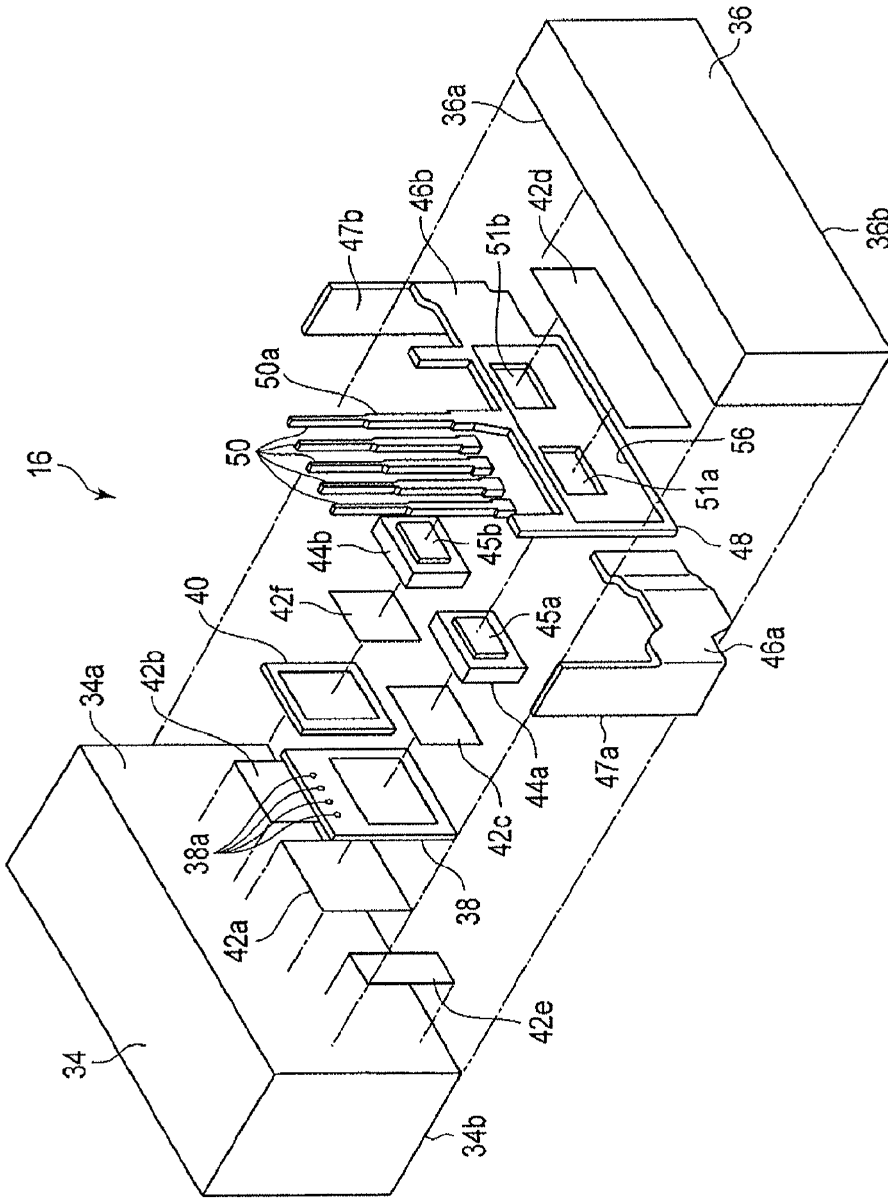

16
36
36a
36b
46b
47b
42d
51b
50a
50
56
51a
48
44b
45b
40
42f
45a
46a
34a
42b
44a
47a
38a
42c
38
42a
42e
34
34b

FIG. 9

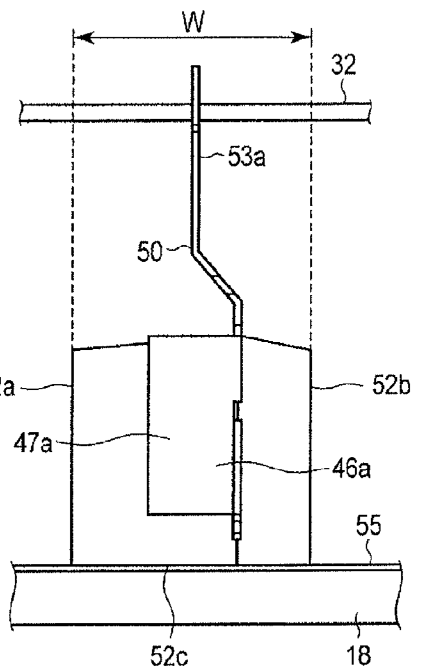

W
32
53a
50
52a
52b
47a
46a
55
52c
18

FIG. 10

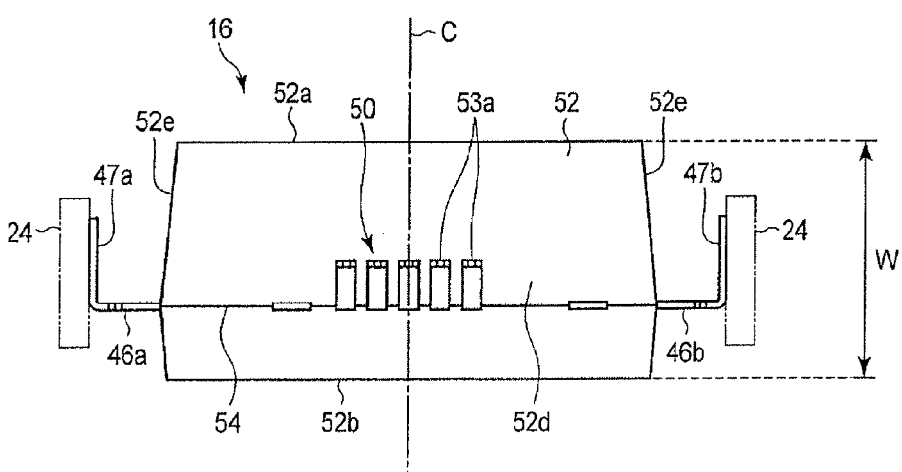
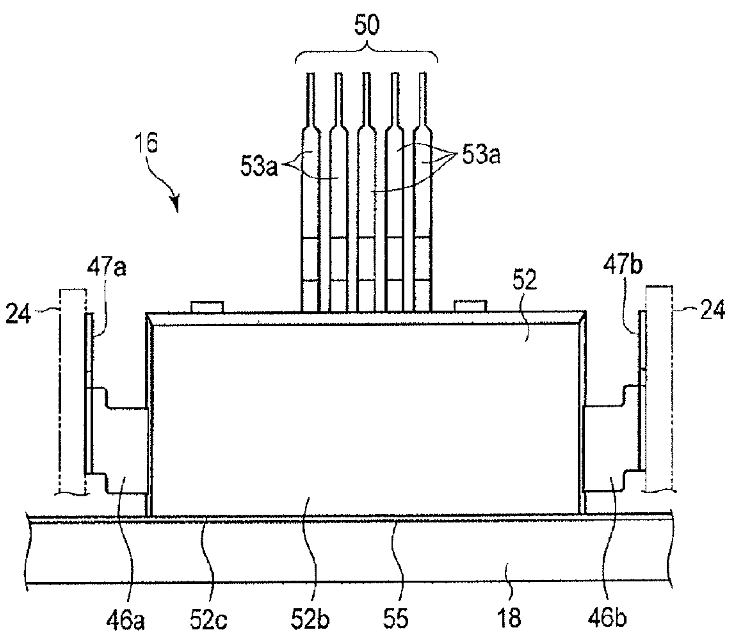

16
C
52a
50
53a
52
52e
52e
47a
47b
24
24
W
46a
46b
54
52b
52d

FIG. 11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16
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53a
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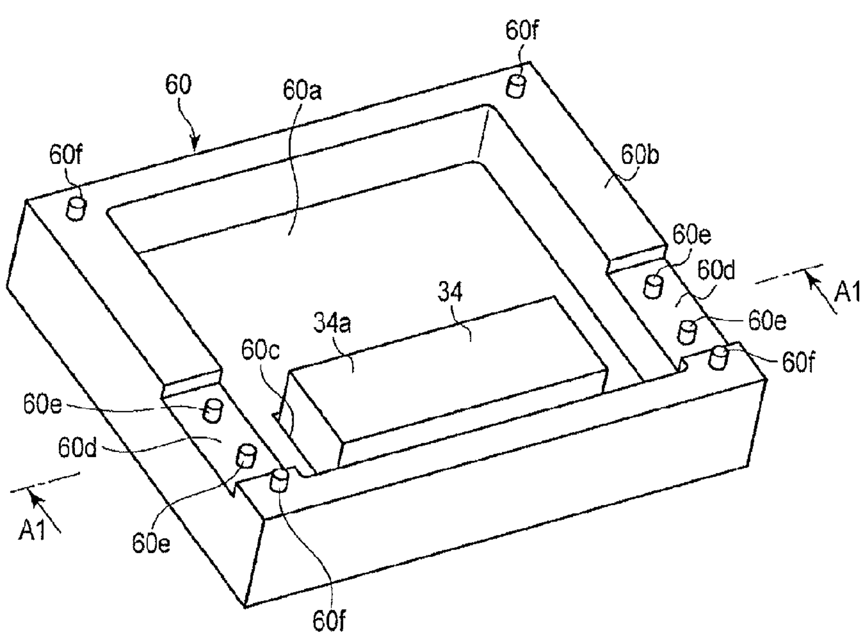
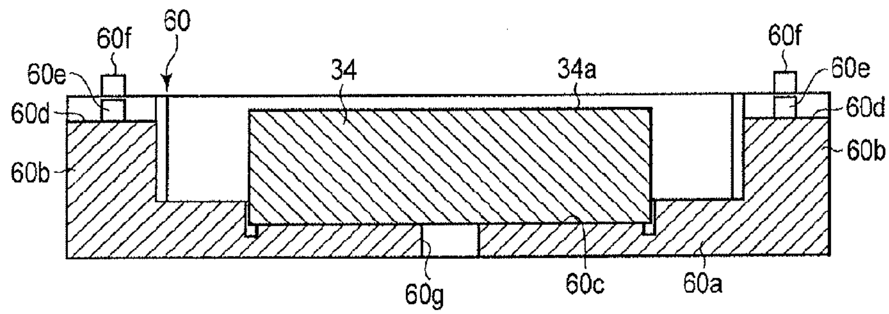
47b
52
24
24
46a
52c
52b
55
18
46b

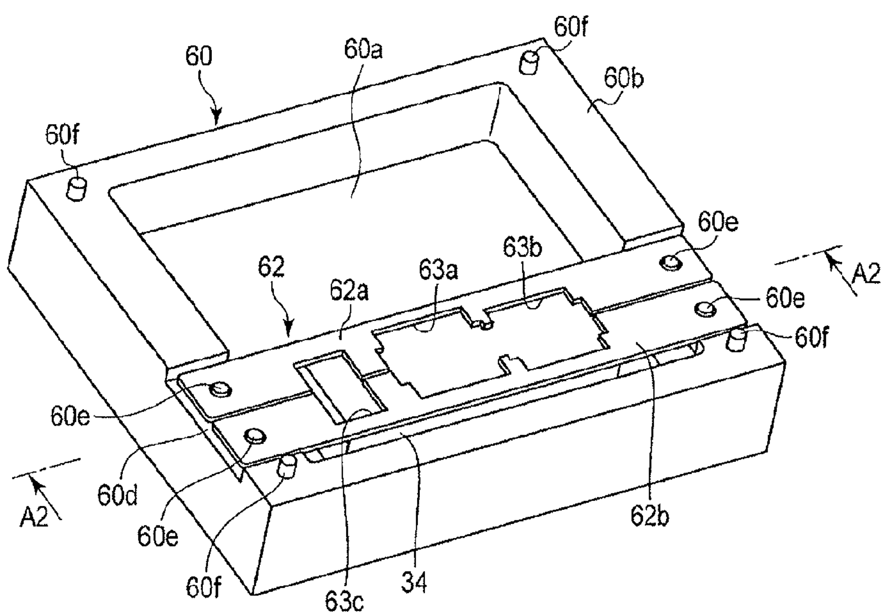
F I G. 12


60f
60
60a
60f
60b
60e
60d
A1
34
34a
60e
60c
60f
60e
60d
A1
60e
60f

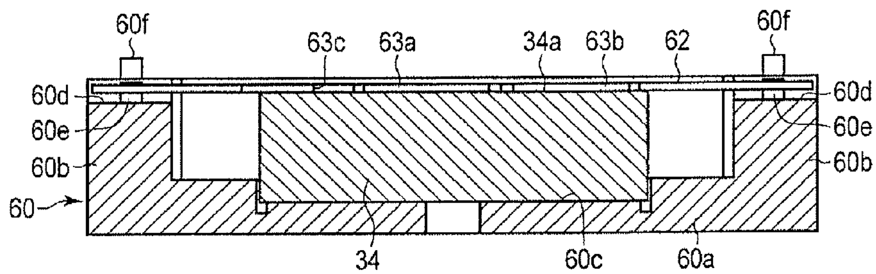
F I G. 13


60f
60
60e
60d
60b
34
34a
60f
60e
60d
60b
60g
60c
60a

F I G. 14


60
60a
60f
60b
60f
62
62a
63a
63b
60e
A2
60e
60f
60e
60d
A2
60e
60f
63c
34
62b

F I G. 15


60f
63c
63a
34a
63b
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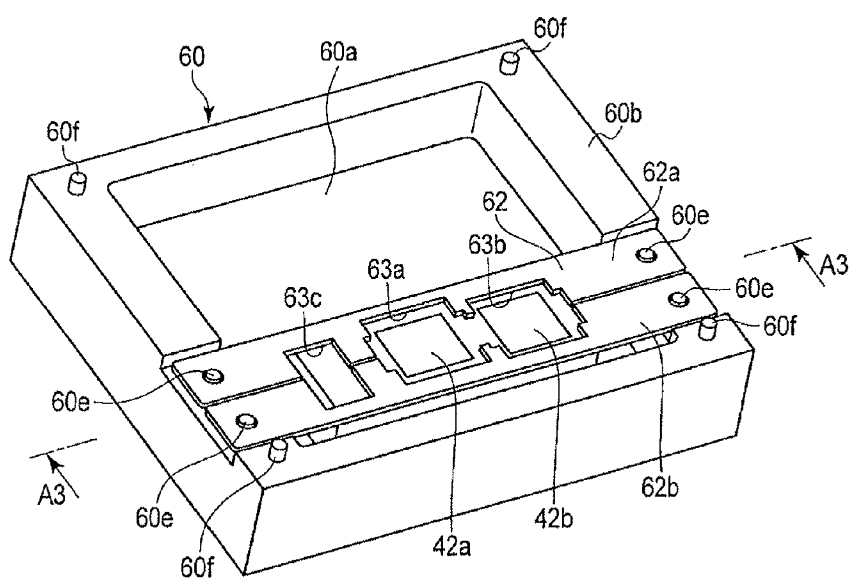
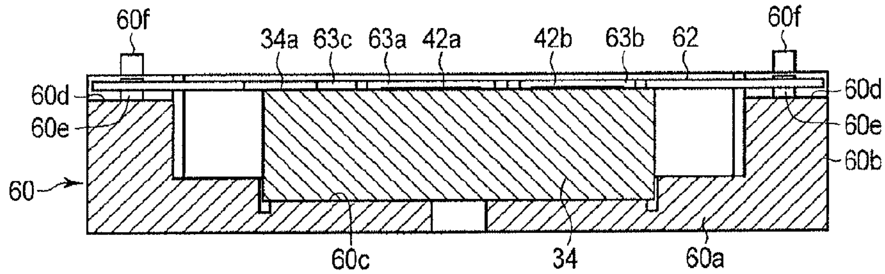
60f
60d
60e
60b
60
60d
60e
60b
34
60c
60a

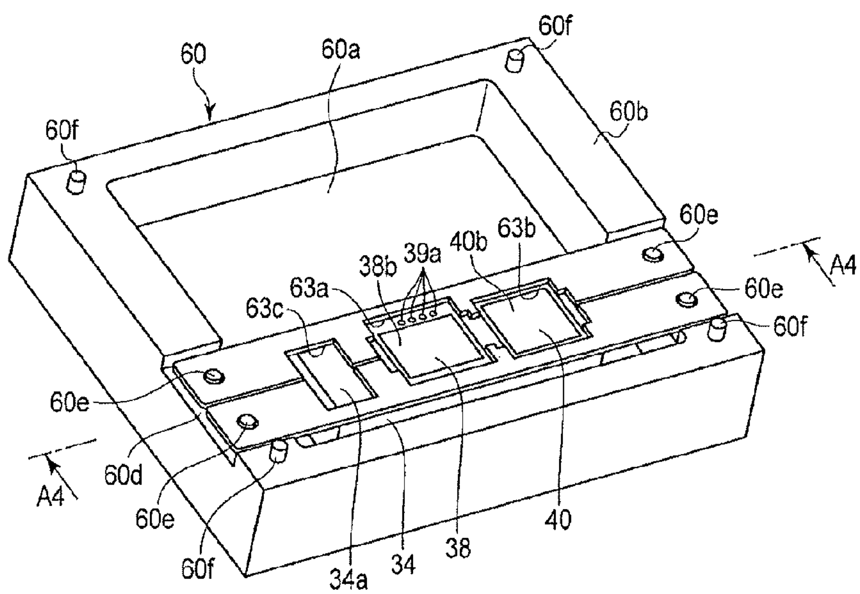
F I G. 16


60
60a
60f
60b
60f
62a
62
60e
63b
63a
A3
63c
60e
60f
60e
60e
A3
60e
60f
62b
42a
42b

F I G. 17


60f
34a
63c
63a
42a
42b
63b
62
60f
60d
60e
60
60d
60e
60b
60c
34
60a

F I G. 18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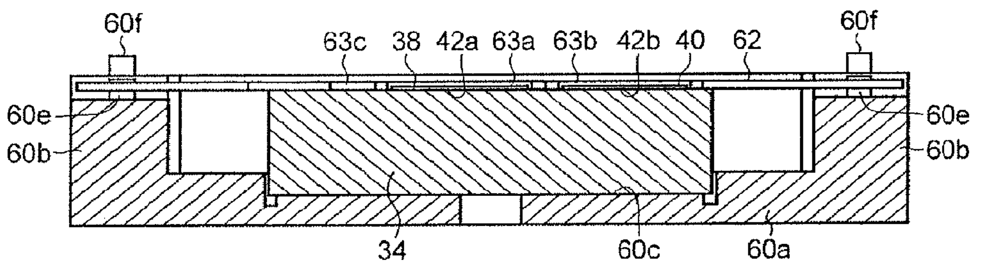
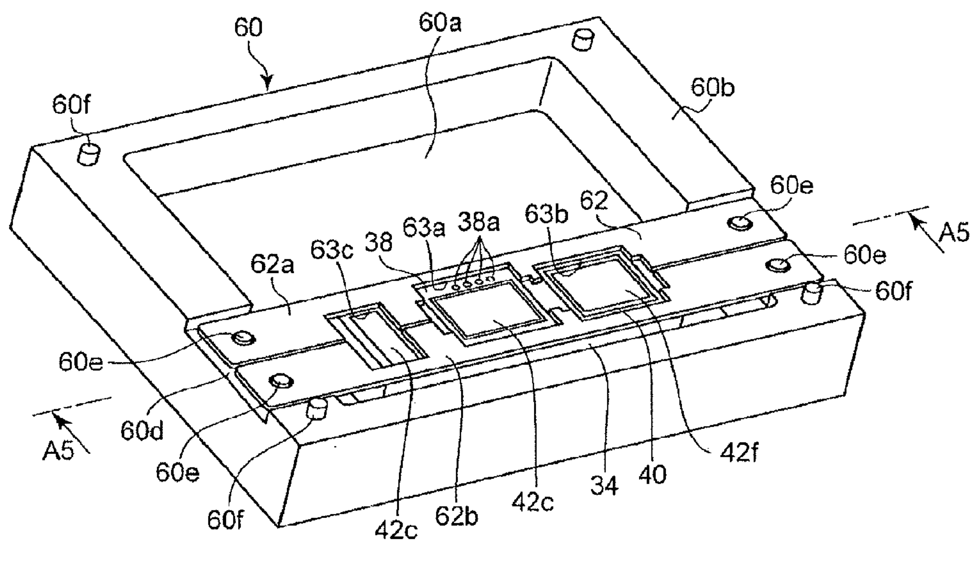
60a
60f
60b
60f
60e
A4
38b
39a
40b
63b
63a
63c
60e
60f
60e
60d
A4
60e
60f
34a
34
38
40

F I G. 19


60f
63c
38
42a
63a
63b
42b
40
62
60f
60e
60b
60e
60b
34
60c
60a

F I G. 20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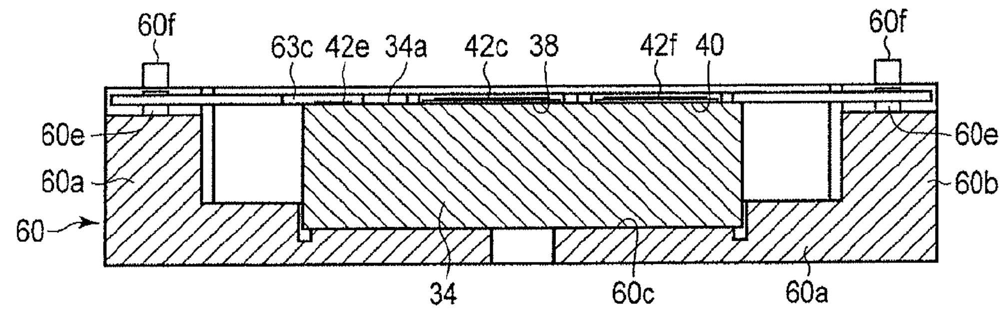
60a
60b
60f
60e
62
63b
63a
38a
38
63c
62a
60e
A5
60f
60e
60d
A5
60e
60f
42c
62b
42c
34
40
42f

F I G. 21


60f
63c
42e
34a
42c
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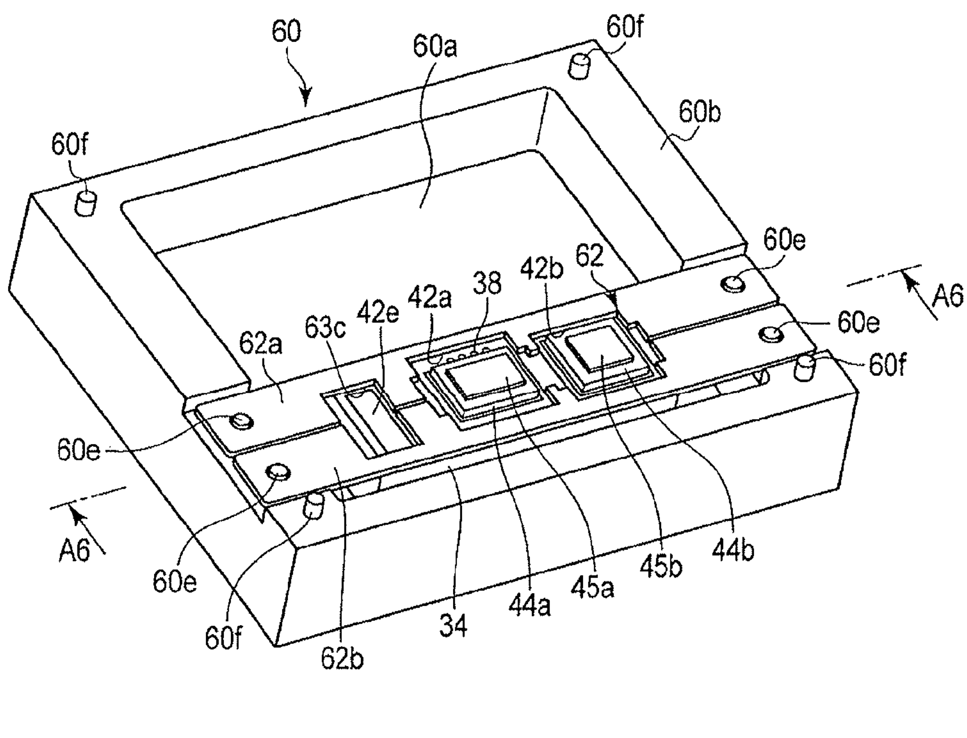
42f
40
60f
60e
60a
60
60e
60b
34
60c
60a

F I G. 22


60
60a
60f
60b
60f
60e
62
42b
38
42a
42e
63c
62a
A6
60e
60f
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60e
A6
60e
60f
62b
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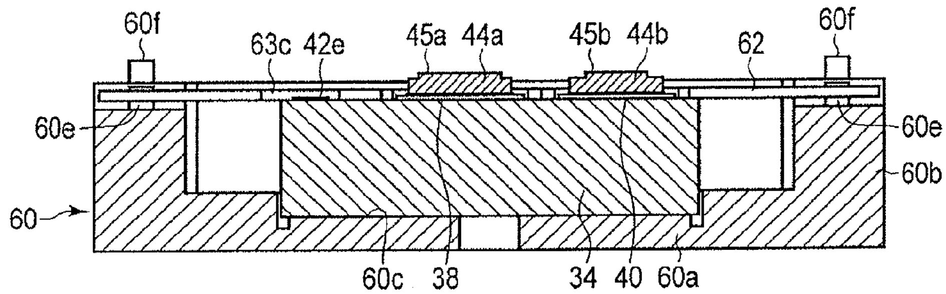
44a
45a
45b
44b

F I G. 23


60f
63c
42e
45a
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45b
44b
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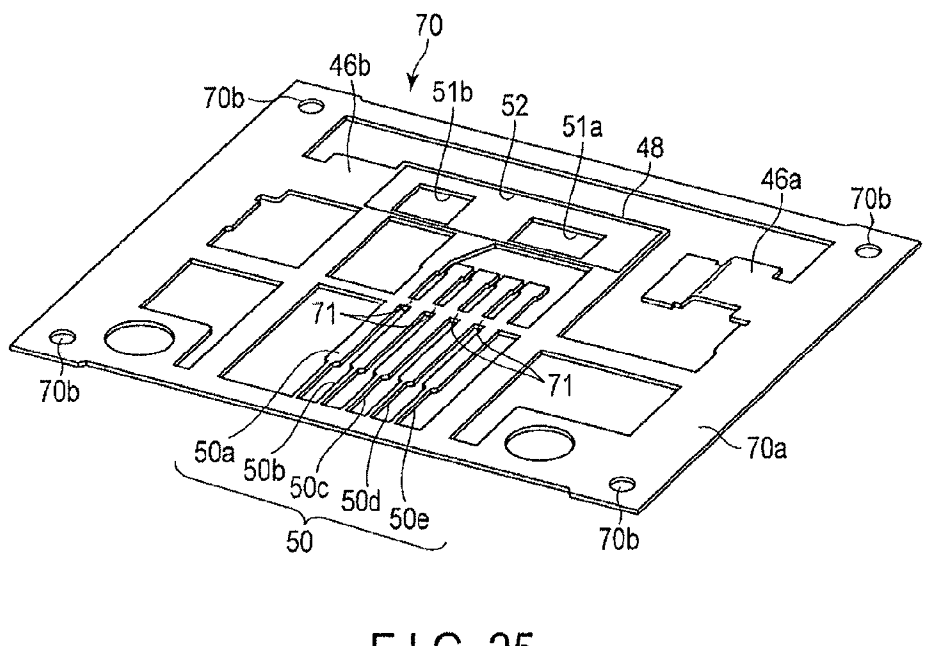
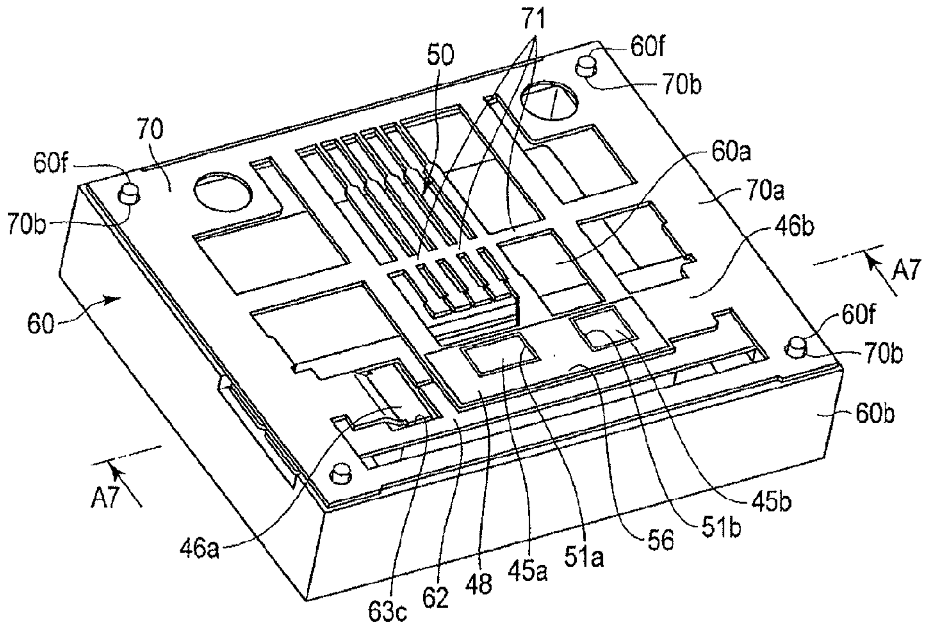
60f
60e
60e
60b
60
60c
38
34
40
60a

F I G. 24


70
46b
70b
51b
52
51a
48
46a
70b
71
71
70b
50a
50b
50c
50d
50e
50
70a
70b

F I G. 25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60f
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45b
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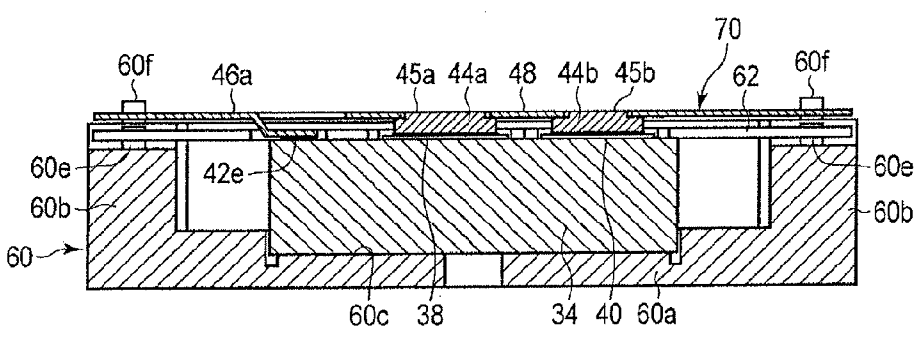
51b
56
51a
45a
48
62
63c

F I G. 26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44b
45b
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60f
60e
42e
60e
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60b
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60c
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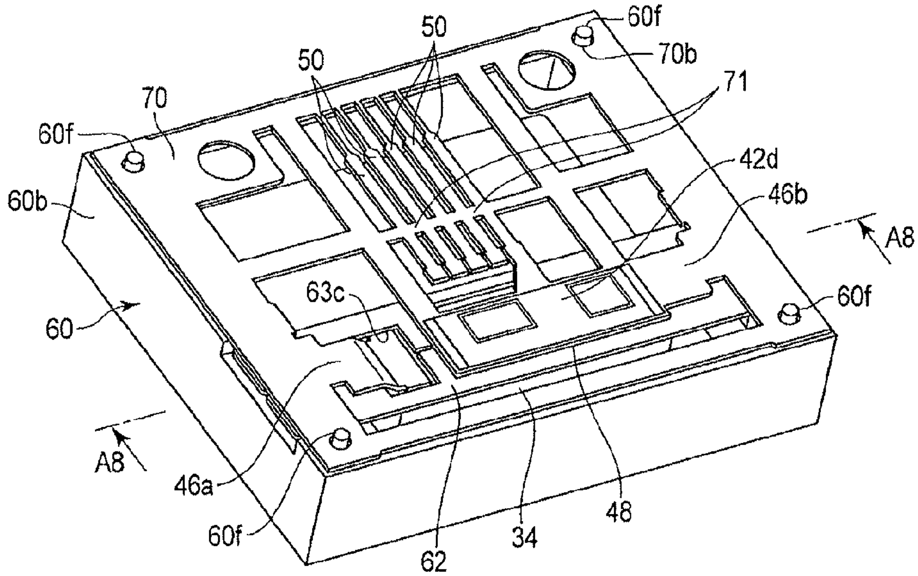
34
40
60a

F I G. 27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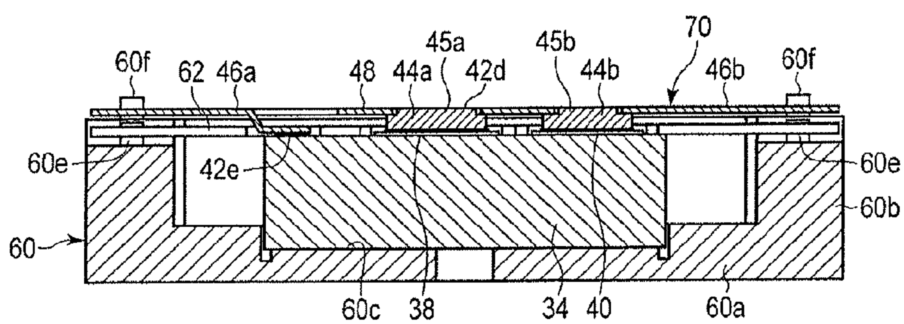
50
70b
70
71
60f
42d
60b
46b
A8
63c
60f
60
A8
46a
60f
48
34
62

F I G. 28


70
45a
45b
60f
62
46a
48
44a
42d
44b
46b
60f
60e
42e
60e
60b
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60c
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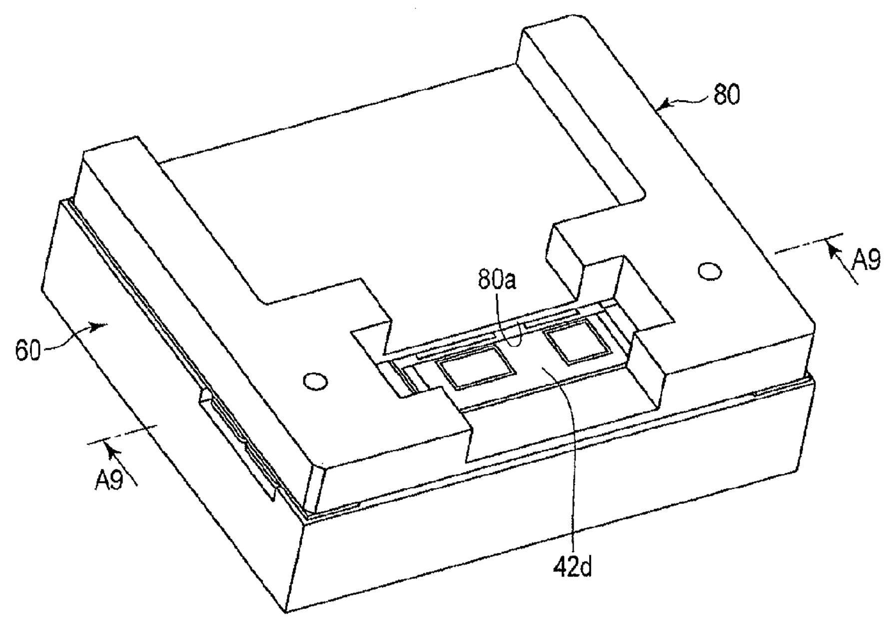
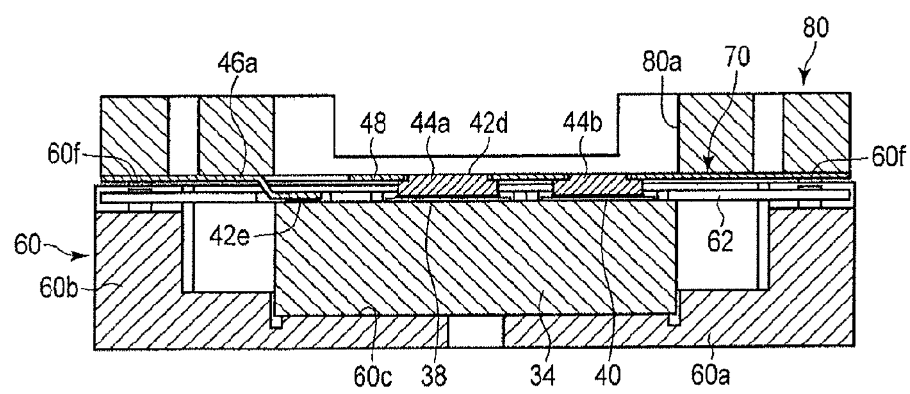
34
40
60a

F I G. 29


80
A9
80a
60
A9
42d

F I G. 30


80
46a
80a
70
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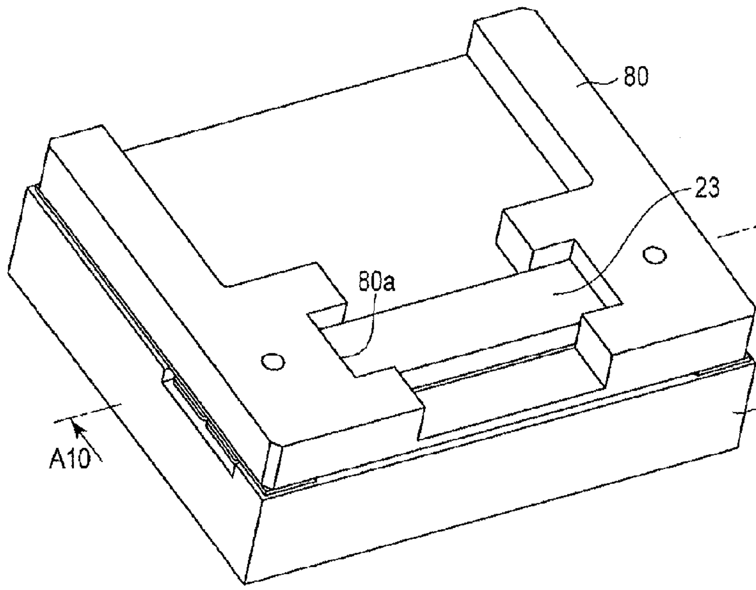
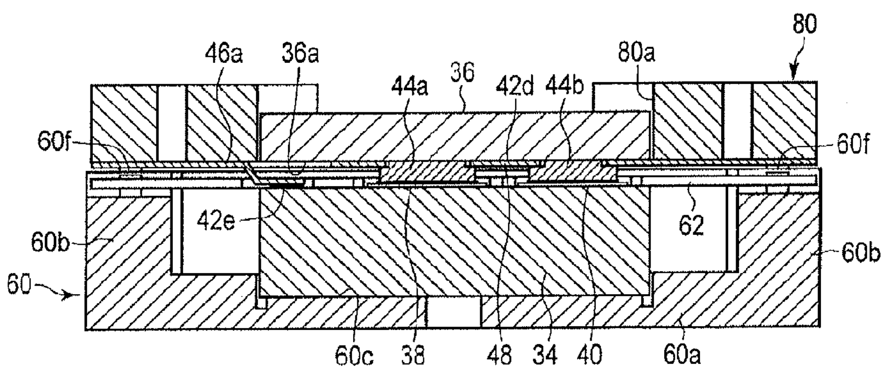
44a
42d
44b
60f
60f
42e
62
60
60b
60c
38
34
40
60a

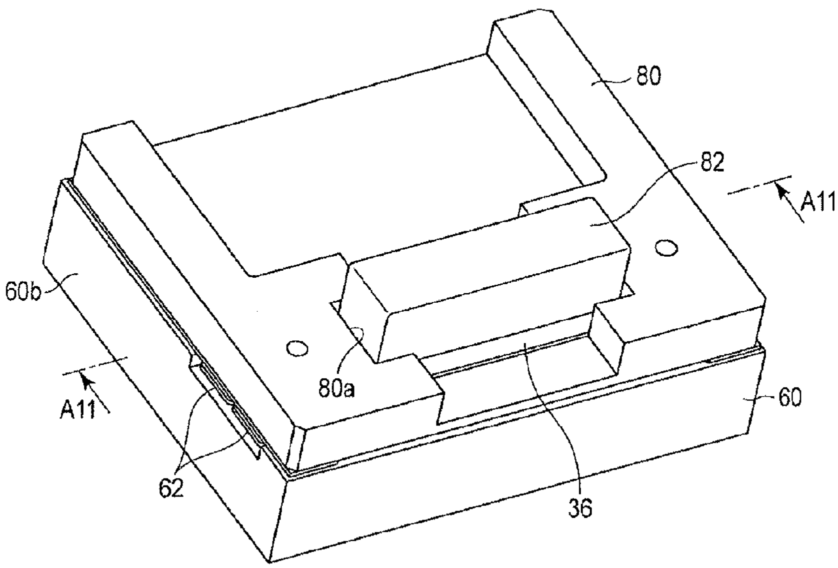
F I G. 31


80
23
A10
80a
60
A10

F I G. 32


80
46a
36a
44a
36
42d
44b
80a
60f
60f
42e
62
60b
60b
60
60c
38
48
34
40
60a

F I G. 33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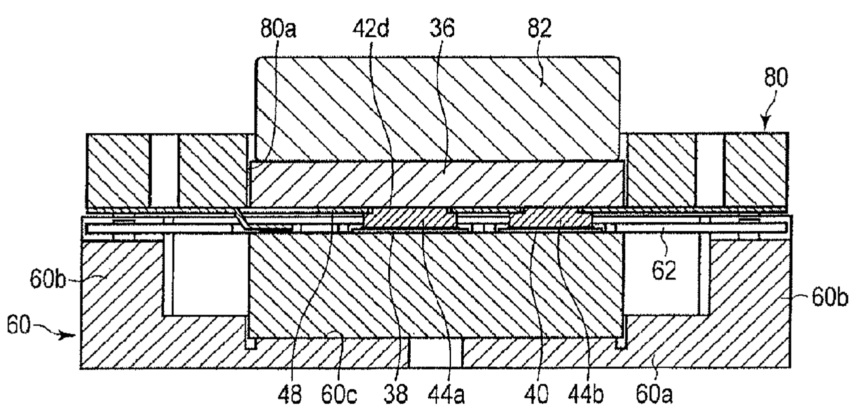
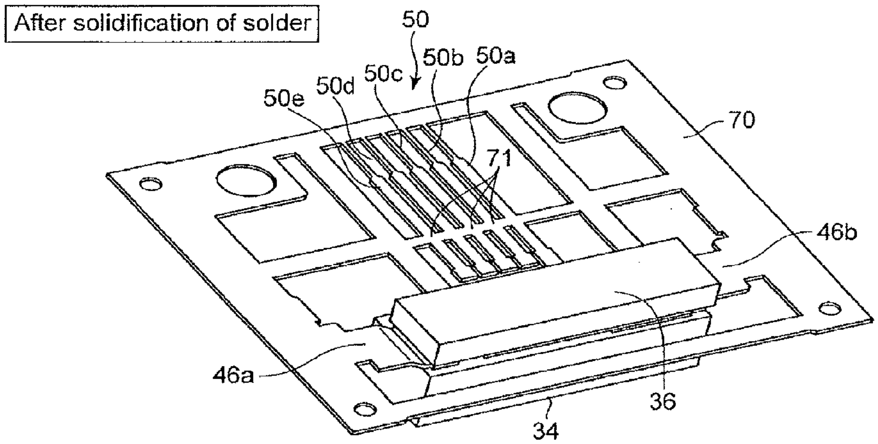
82
A11
60b
A11
80a
60
62
36

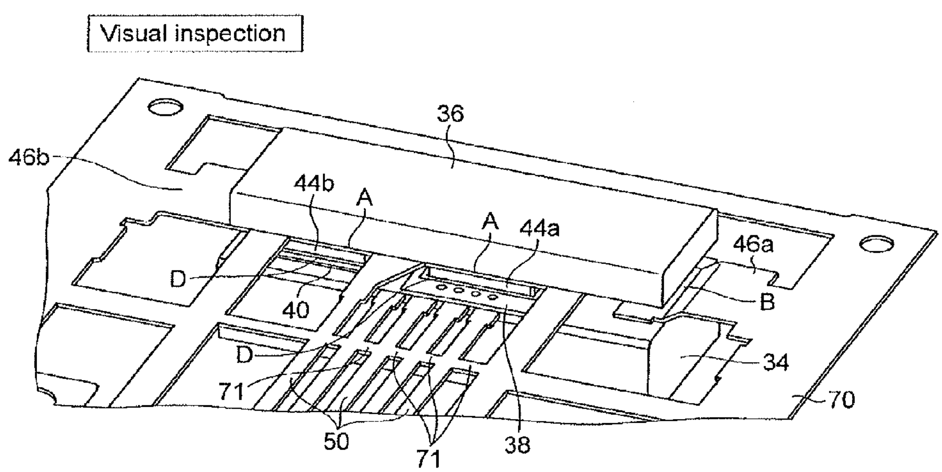
F I G. 34


80a
42d
36
82
80
60b
62
60b
60
48
60c
38
44a
40
44b
60a

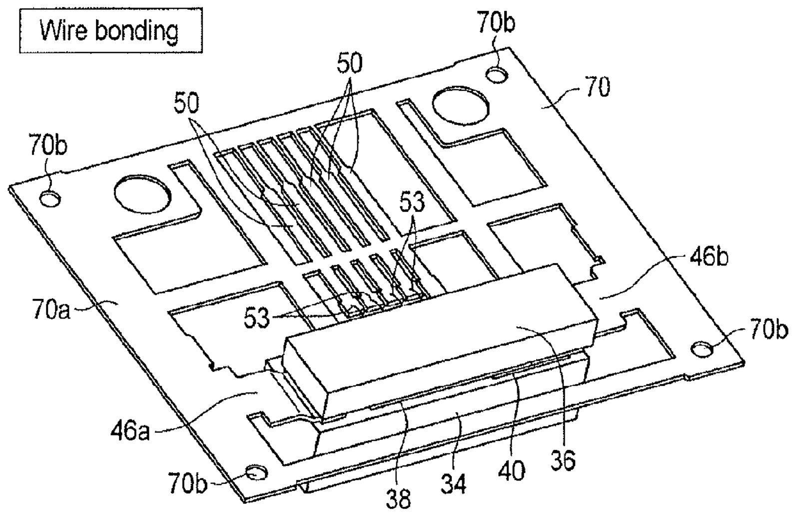
F I G. 35


After solidification of solder
50
50a
50b
50c
50d
50e
70
71
46b
46a
36
34

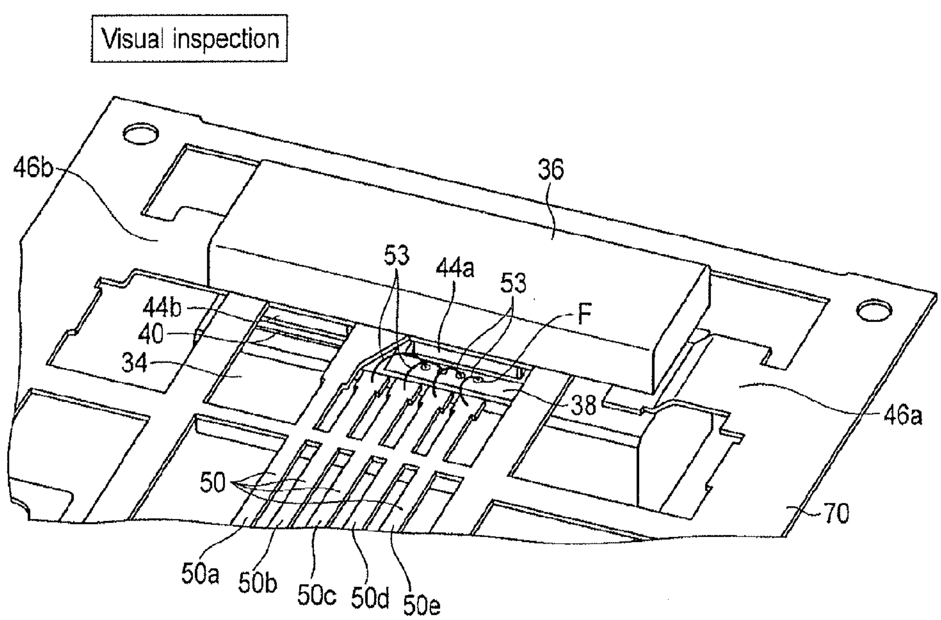
F I G. 36


Visual inspection
36
46b
44b
A
A
44a
46a
D
40
B
D
34
71
70
50
71
38

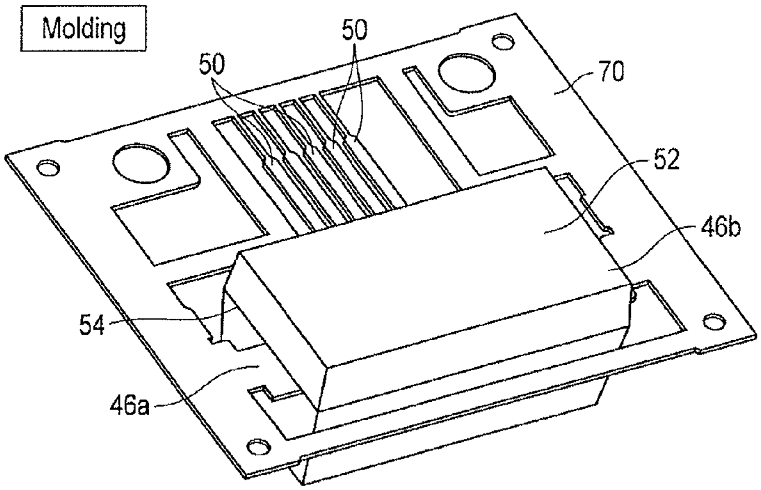
F I G. 37


Wire bonding
70b
50
70
50
70b
53
46b
70a
53
70b
46a
70b
38
34
40
36

F I G. 38

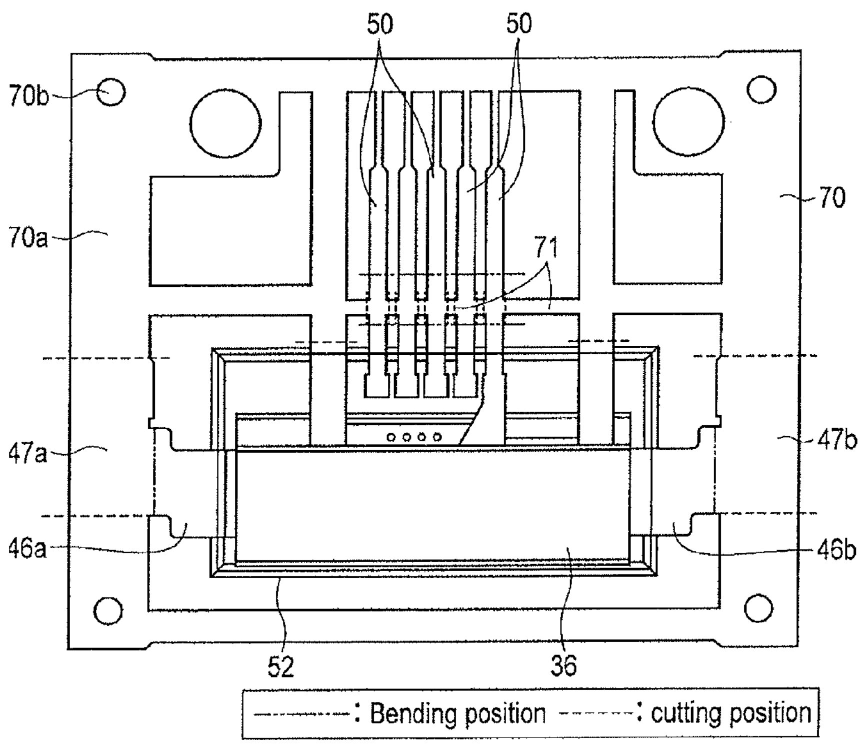

Visual inspection
46b
36
53
44a
53
44b
F
40
34
38
46a
50
70
50a
50b
50c
50d
50e

F I G. 39



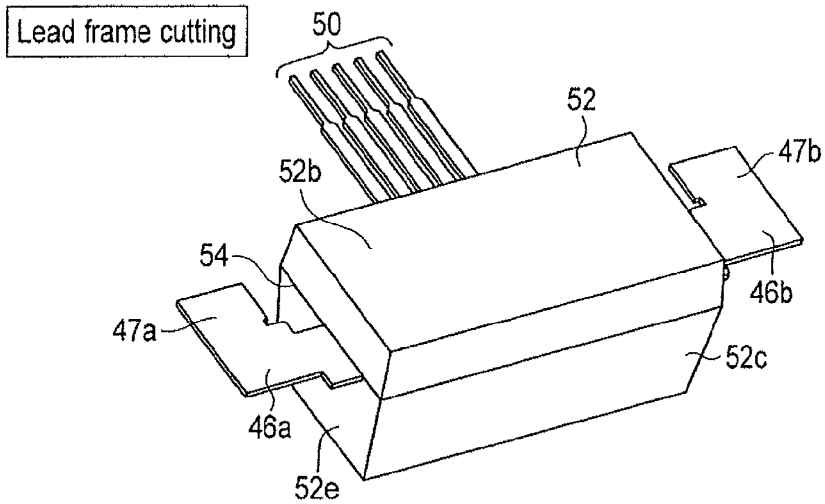
Molding
50
50
70
52
46b
54
46a

F I G. 40

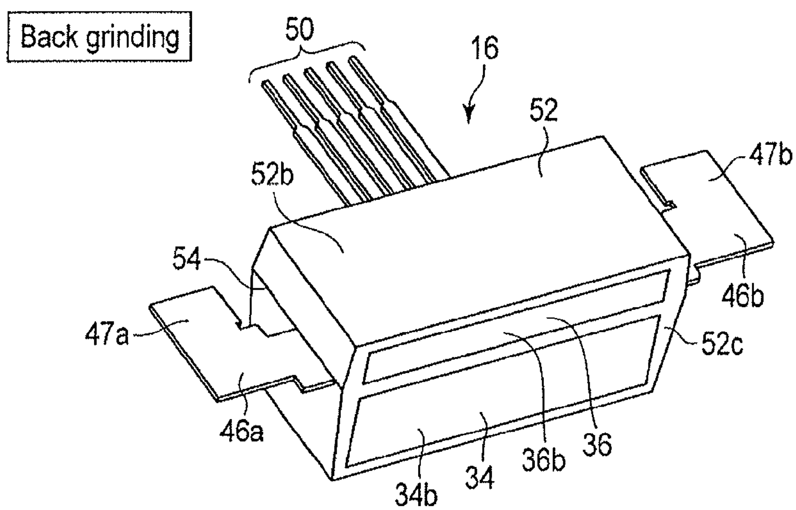


50
50
70b
70
70a
71
47a
47b
46a
46b
52
36
------- : Bending position ------ : cutting position

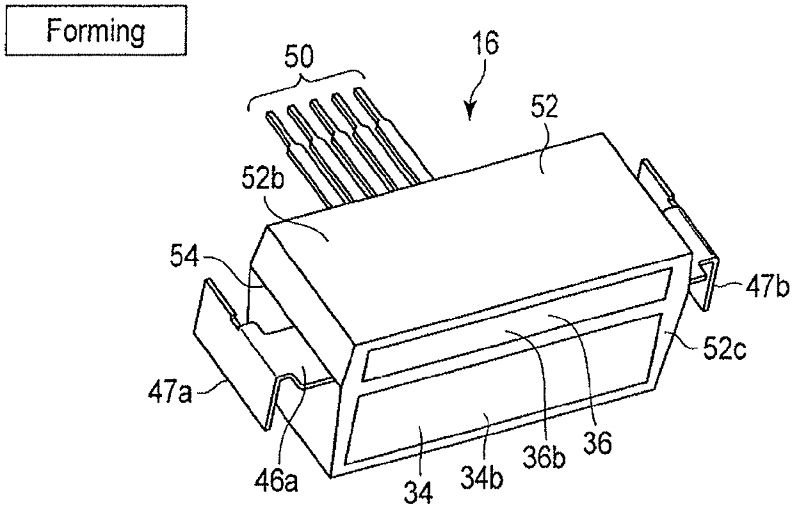
F I G. 41


Lead frame cutting
50
52
47b
52b
54
46b
47a
52c
46a
52e

F I G. 42

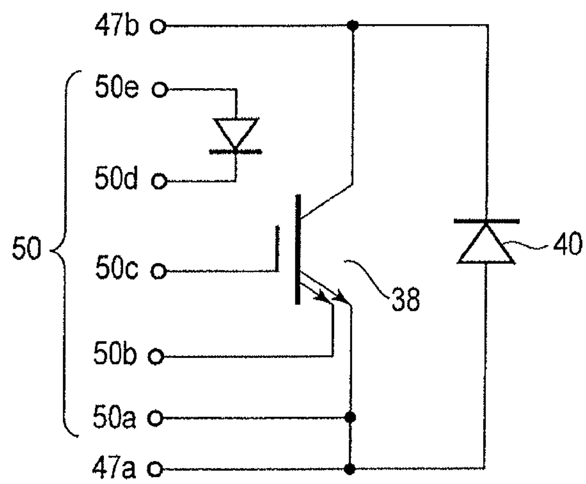

Back grinding
50
16
52
52b
47b
54
46b
47a
52c
46a
36b
36
34b
34

F I G. 43



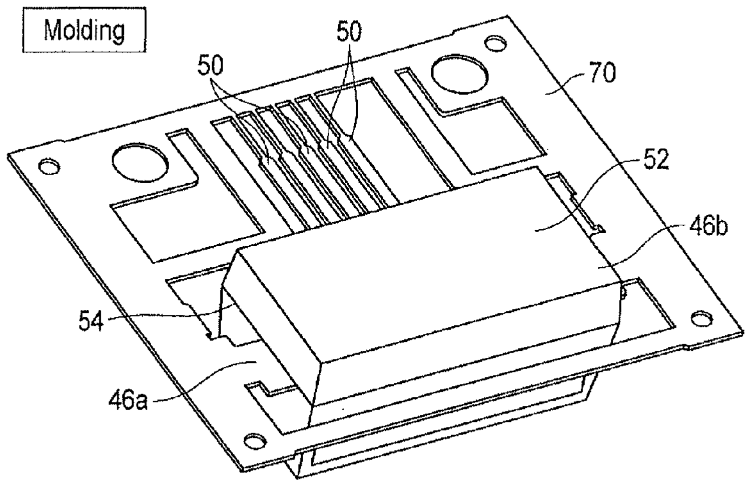
Forming
50
16
52
52b
54
47b
52c
47a
46a
34
34b
36b
36

F I G. 44



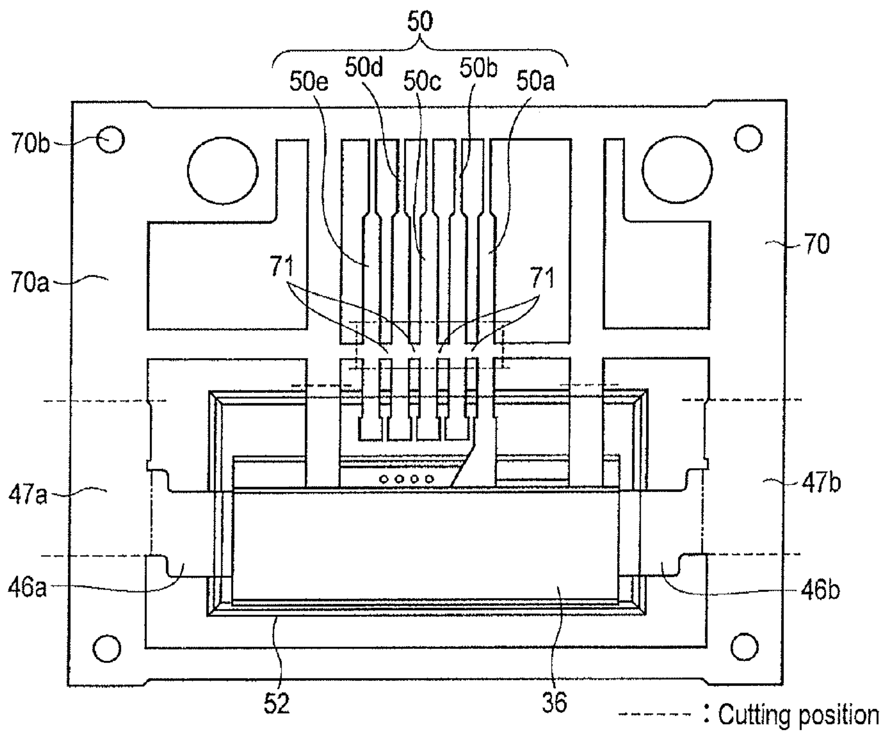
47b
50e
50d
50
50c
50b
50a
47a
40
38

F I G. 45



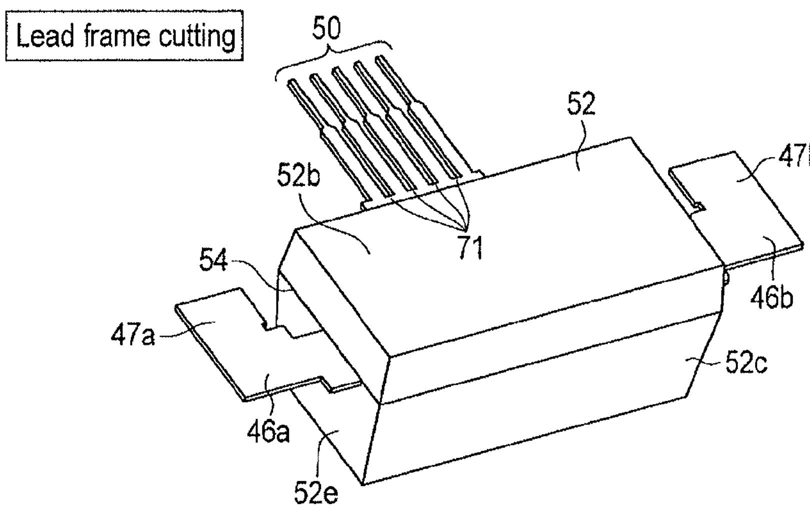
Molding
50
50
70
52
46b
54
46a

F I G. 46

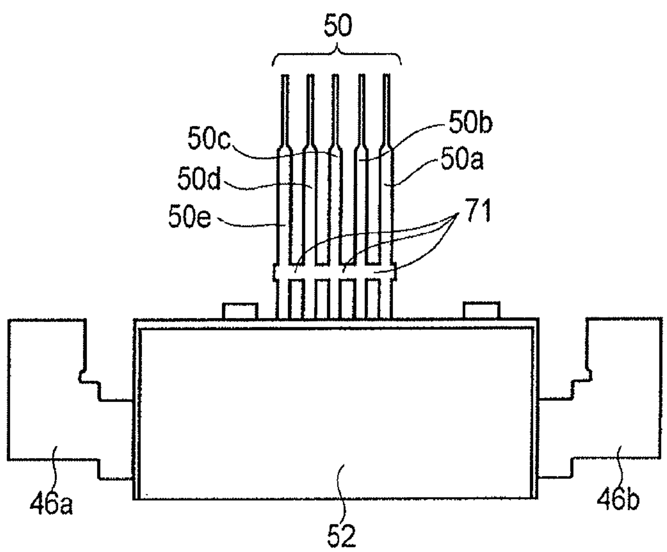


50
50e
50d
50c
50b
50a
70b
70
70a
71
71
47a
47b
46a
46b
52
36
------- : Cutting position

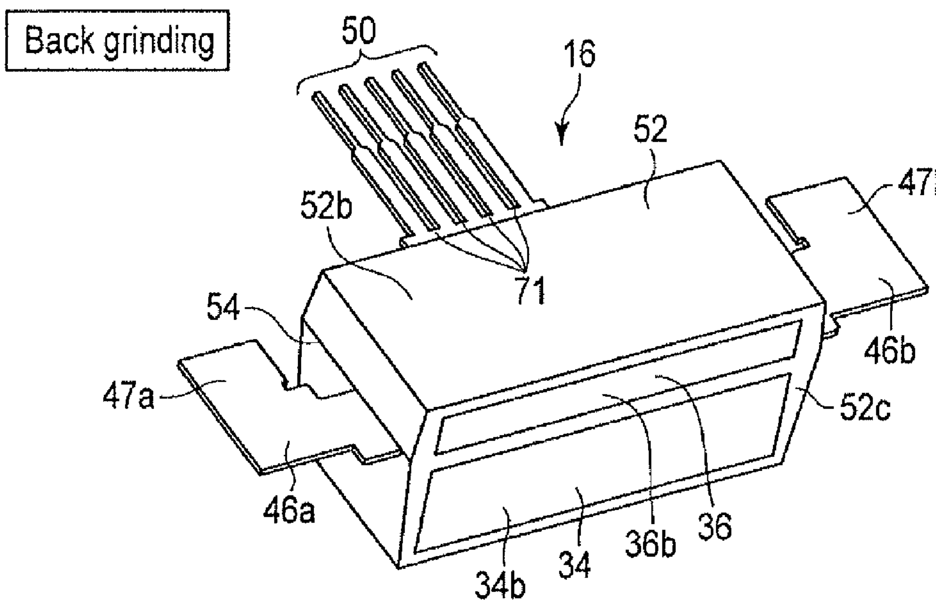
F I G. 47


Lead frame cutting
50
52
47b
52b
71
54
46b
47a
52c
46a
52e

F I G. 48


50
50b
50c
50a
50d
50e
71
46a
46b
52

F I G. 49


Back grinding
50
16
52
52b
71
47b
54
46b
47a
52c
46a
34b
34
36b
36

F I G. 50

SEMICONDUCTOR POWER CONVERTER AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Applications No. 2012-240990, filed Oct. 31, 2012; and No. 2013-137218, filed Jun. 28, 2013, the entire contents of all of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a semiconductor power converter and a method of manufacturing the same.

BACKGROUND

In recent years, hybrid vehicles that use an engine and a motor in combination have rapidly become widely used to achieve higher fuel efficiency. On the other hand, marketing of electric vehicles that can run by a motor alone is in progress. To be feasible, these vehicles require use of a power converter for AC/DC conversion between a battery and the motor.

In the hybrid and electric vehicles, the semiconductor power converter is expected to be small and highly reliable. To this end, the power converter requires high cooling efficiency. As a measure to achieve this, a power converter structure of the double-sided cooling type has been proposed in which electrical conductors are connected individually to the obverse and reverse surfaces of a semiconductor element and heat is released from the electrical conductors to a cooler.

In assembling a power converter of the double-sided cooling type, joining work is required in at least two positions to join the semiconductor element and the electrical conductors on its opposite surfaces. Further, there is a problem that the number of assembly man-hours increases if joining of power terminals and signal terminals is taken into account. If the joining positions increase, moreover, the number of man-hours for the inspection of joint soundness increases, and assembly errors are accumulated so that finished-product dimensional stability is reduced.

A mounter is assumed to be used to enhance mass-productivity. In this case, parts may become misaligned due to shaky transportation or flow of melted connecting bodies, possibly reducing the assembly yield.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing a semiconductor power converter according to a first embodiment with its circuit board removed;

FIG. **2** is a perspective view showing a support frame and cooler of the semiconductor power converter;

FIG. **3** is a perspective view showing the entire semiconductor power converter including the control circuit board;

FIG. **4** is a perspective view showing a semiconductor module of the semiconductor power converter;

FIG. **5** is a perspective view of the semiconductor module taken in a different direction;

FIG. **6** is a perspective view showing the internal structure of the semiconductor module seen through a mold;

FIG. **7** is a perspective view showing the internal structure of the semiconductor module seen through the mold;

FIG. **8** is a plan view showing the internal structure of the semiconductor module seen through the mold;

FIG. **9** is an exploded perspective view showing constituent parts of the semiconductor module;

FIG. **10** is a side view showing the semiconductor module;

FIG. **11** is a plan view showing the semiconductor module;

FIG. **12** is a front view showing the semiconductor module;

FIG. **13** is a perspective view of a first fixing jig and first electrical conductor showing a process of manufacturing the semiconductor module;

FIG. **14** is a sectional view of the first fixing jig and first electrical conductor taken along line **A1**-**A1** of FIG. **13**;

FIG. **15** is a perspective view of the first fixing jig, the first electrical conductor, and a split jig showing a process of manufacturing the semiconductor module;

FIG. **16** is a sectional view taken along line **A2**-**A2** of FIG. **15**;

FIG. **17** is a perspective view showing how first and second connecting bodies are placed in a process of manufacturing the semiconductor module;

FIG. **18** is a sectional view taken along line **A3**-**A3** of FIG. **17**;

FIG. **19** is a perspective view showing how first and second semiconductor elements are placed on the first and second connecting bodies, respectively, in a process of manufacturing the semiconductor module;

FIG. **20** is a sectional view taken along line **A4**-**A4** of FIG. **19**;

FIG. **21** is a perspective view showing how third and fourth connecting bodies are placed on the first and second semiconductor elements, respectively, in a process of manufacturing the semiconductor module;

FIG. **22** is a sectional view taken along line **A5**-**A5** of FIG. **21**;

FIG. **23** is a perspective view showing how first and second convex electrical conductors are placed on the third and fourth connecting bodies, respectively, in a process of manufacturing the semiconductor module;

FIG. **24** is a sectional view taken along line **A6**-**A6** of FIG. **23**;

FIG. **25** is a perspective view showing a lead frame used in the manufacturing processes;

FIG. **26** is a perspective view showing how the lead frame is placed on the first fixing jig and first and second convex electrical conductors in a process of manufacturing the semiconductor module;

FIG. **27** is a sectional view taken along line **A7**-**A7** of FIG. **26**;

FIG. **28** is a perspective view showing how a sixth connecting body is placed on the lead frame in a process of manufacturing the semiconductor module;

FIG. **29** is a sectional view taken along line **A8**-**A8** of FIG. **28**;

FIG. **30** is a perspective view showing how a second fixing jig is placed on the first fixing jig and lead frame in a process of manufacturing the semiconductor module;

FIG. **31** is a sectional view taken along line **A9**-**A9** of FIG. **30**;

FIG. **32** is a perspective view showing how a second electrical conductor is placed on the second fixing jig in a process of manufacturing the semiconductor module;

FIG. **33** is a sectional view taken along line **A10**-**A10** of FIG. **32**;

FIG. 34 is a perspective view showing how a counterweight is mounted on the second electrical conductor in a process of manufacturing the semiconductor module;

FIG. 35 is a sectional view taken along line A11-A11 of FIG. 34;

FIG. 36 is a perspective view showing a state in which constituent members are joined together with solder and the first and second fixing jigs and split jig are removed, in a process of manufacturing the semiconductor module;

FIG. 37 is a perspective view showing a visual inspection process in a process of manufacturing the semiconductor module;

FIG. 38 is a perspective view showing a wire-bonding process in a process of manufacturing the semiconductor module;

FIG. 39 is a perspective view showing a visual inspection process after wire bonding in a process of manufacturing the semiconductor module;

FIG. 40 is a perspective view showing a resin molding process in a process of manufacturing the semiconductor module;

FIG. 41 is a plan view of the semiconductor module showing cutting positions and bending positions of the lead frame in a process of manufacturing the semiconductor module;

FIG. 42 is a perspective view showing a lead frame cutting process in a process of manufacturing the semiconductor module;

FIG. 43 is a perspective view showing a process of grinding the bottom of a molded resin body in a process of manufacturing the semiconductor module;

FIG. 44 is a perspective view showing a process of bend-forming first and second power terminals and signal terminals in a process of manufacturing the semiconductor module;

FIG. 45 is a diagram showing an equivalent circuit of the semiconductor module;

FIG. 46 is a perspective view showing a resin molding process in a process of manufacturing a semiconductor module according to a second embodiment;

FIG. 47 is a plan view of the semiconductor module of the second embodiment showing cutting positions and bending positions of a lead frame in a process of manufacturing the semiconductor module;

FIG. 48 is a perspective view showing a lead frame cutting process in a process of manufacturing the semiconductor module of the second embodiment;

FIG. 49 is a side view showing the semiconductor module of the second embodiment with the lead frame cut in a process of manufacturing the semiconductor module; and

FIG. 50 is a perspective view showing a process of grinding the bottom of a molded resin body in a process of manufacturing the semiconductor module of the second embodiment.

DETAILED DESCRIPTION

Various embodiments will be described hereinafter with reference to the accompanying drawings. In general, according to one embodiment, a semiconductor power converter comprises: a first electrical conductor comprising a first joint surface and a first bottom surface perpendicular to the first joint surface; a second electrical conductor comprising a second joint surface opposed parallel to the first joint surface and a second bottom surface located perpendicular to the second joint surface and flush with the first bottom surface; a plate-shaped first semiconductor element comprising different electrodes on the obverse and reverse surfaces thereof, one of the electrodes being joined to the first joint surface of the first electrical conductor by a first connecting body and disposed parallel to the first joint surface; a plate-shaped second semiconductor element comprising different electrodes on the obverse and reverse surfaces thereof, one of the electrodes being joined to the first joint surface of the first electrical conductor by a second connecting body and disposed parallel to the first joint surface; a first convex electrical conductor joined to the other electrode of the first semiconductor element by a third connecting body and comprising a projection projecting toward the second joint surface; a second convex electrical conductor joined to the other electrode of the second semiconductor element by a fourth connecting body and comprising a projection projecting toward the second joint surface; a junction formed of an electrically conductive metal plate and comprising a first positioning opening in which the projection of the first convex electrical conductor is fitted and a second positioning opening in which the projection of the second convex electrical conductor is fitted and joined to the first and second convex electrical conductors and the second joint surface of the second electrical conductor by a sixth connecting body; a first power terminal comprising a proximal end portion joined to the first joint surface by a fifth connecting body and extending outwardly from the first electrical conductor; a second power terminal extending outwardly relative to the second electrical conductor from the junction; signal terminals connected to the first semiconductor element; and an envelope which covers and seals the proximal end portion of the first power terminal, a proximal end portion of the second power terminal, a proximal end portion of the signal terminal, and the other constituent members. The envelope comprises a flat bottom surface which extends perpendicular to the first and second semiconductor elements and in which the first bottom surface of the first electrical conductor and the second bottom surface of the second electrical conductor are exposed.

The drawings are schematic views for a better understanding of the embodiments, and the shapes, sizes, proportions, etc., shown therein may be different from actual specifications. However, they may be suitably designed and modified in consideration of the following description and known techniques.

First Embodiment

FIG. 1 is a perspective view showing a semiconductor power converter according to a first embodiment with its control circuit board removed. FIG. 2 is a perspective view showing a support frame and cooler of the semiconductor power converter, and FIG. 3 is a perspective view showing the entire semiconductor power converter including the control circuit board.

As shown in FIGS. 1 to 3, a semiconductor power converter 10 comprises a cooler 12, support frame 14, and a plurality of semiconductor modules 16. The support frame 14 is secured on the cooler 12. The semiconductor modules 16 are set on the cooler and supported by the support frame. The cooler 12 comprises a flat cuboid cooling block 18 with a flat rectangular heat receiving surface 18a. The cooling block 18 is made of, for example, aluminum. Further, a refrigerant passage 20 through which a cooling medium, such as water, is passed is formed in the cooling block 18.

The support frame 14 integrally comprises a rectangular outer frame of a size corresponding to the heat receiving surface 18a and a plurality of coupling beams extending parallel to one another inside the outer frame. The outer frame and coupling beams define rectangular installation space portions 22 arranged in, for example, four rows. Further, the support frame 14 comprises bus bars 26, input terminals 28, and two sets of three-phase output terminals **30**. Each bus bar **26** comprises a plurality of connecting terminals **24** electrically connected to the semiconductor modules **16**, which will be described later. The connecting terminals **24** of the bus bars **26** are arranged at intervals along each side edge of each installation space portion **22**. The support frame **14** is formed integrally with the terminals by, for example, insert-molding a resin. Furthermore, the support frame **14** is secured on the heat receiving surface **18***a* of the cooling block **18** by, for example, screws.

As shown in FIG. **1**, the semiconductor modules **16** are located, for example, in four rows each comprising six modules, on the support frame **14**. In each row, the six semiconductor modules **16** are disposed in their corresponding installation space portion **22** of the support frame **14**, and the bottom surface of each semiconductor module is located on the heat receiving surface **18***a* of the cooler **12** with an insulating sheet (not shown) therebetween. Respective power terminals of the semiconductor modules **16** contact their corresponding connecting terminals **24** of the bus bars **26** and are electrically connected to the bus bars **26**. Further, a plurality of signal terminals **50** of each semiconductor module **16** project upwardly.

As shown in FIG. **3**, the semiconductor power converter **10** comprises a control circuit board **32**, which controls the input/output and other operations of the semiconductor modules **16** and the entire device. The control circuit board **32** is in the form of a rectangular structure substantially as large as the support frame **14**. The control circuit board **32** is superposed on the semiconductor modules **16** and attached to the support frame **14** by fixing screws (not shown) or the like. The signal terminals **50** of the semiconductor modules **16** are electrically connected to the control circuit board **32**.

The following is a detailed description of one of the semiconductor modules **16** that constitute the semiconductor power converter.

FIGS. **4** and **5** are perspective views showing the semiconductor module, FIGS. **6**, **7** and **8** are perspective views and a plan view showing the internal structure of the semiconductor module seen through a molded resin body, and FIG. **9** is an exploded perspective view showing constituent parts of the semiconductor module. FIGS. **10**, **11** and **12** are side, plan, and front views, respectively, of the semiconductor module.

As shown in FIGS. **4** to **9**, the semiconductor module **16** is constructed as a power converter of the so-called double-sided cooling and vertical-mounting type. Specifically, the semiconductor module **16** comprises block-shaped first and second electrical conductors (collector and emitter) **34** and **36** of, for example, copper and first and second semiconductor elements **38** and **40** interposed between and joined to the first and second electrical conductors.

One principal surface (lateral surface) of the first electrical conductor **34** constitutes a rectangular joint surface (first joint surface) **34***a*, and a bottom surface **34***b* perpendicular to this joint surface constitutes a radiating surface. The second electrical conductor **36** is substantially as long as the first electrical conductor **34** and its thickness (width) is smaller than (for example, about a third of) that of the first electrical conductor **34**. Further, the second electrical conductor **36** is less tall than the first electrical conductor **34**. One principal surface (lateral surface) of the second electrical conductor **36** constitutes a rectangular joint surface (second joint surface) **36***a*, and moreover, a bottom surface **36***b* perpendicular to this joint surface constitutes a radiating surface. Joint surface **36***a* of the second electrical conductor **36** is opposed parallel to joint surface **34***a* of the first electrical conductor **34**. Bottom surface **36***b* is located flush with bottom surface **34***b* of the first electrical conductor **34**.

The first semiconductor element **38** is a power semiconductor element, for example, an insulator gate bipolar transistor (IGBT), while the second semiconductor element **40** is a diode. The first semiconductor element **38** is a rectangular plate formed with different electrodes on its obverse and reverse surfaces. Further, a plurality (for example, four) of connecting terminals **38***a* are formed on one surface of the first semiconductor element **38**. The entire surfaces of the first semiconductor element **38** except areas for the electrodes and connecting terminals are covered by an insulating film of, for example, polyimide.

The second semiconductor element **40** is a rectangular plate formed with different electrodes on its obverse and reverse surfaces. The entire surfaces of the second semiconductor element **40** except rectangular areas for the electrodes are covered by an insulating film of, for example, polyimide.

The first semiconductor element **38** is disposed parallel to joint surface **34***a* of the first electrical conductor **34**, and its one electrode (collector) is joined to joint surface **34***a* of the first electrical conductor **34** with a first connecting body, for example, a rectangular solder sheet **42***a*, therebetween. The second semiconductor element **40** is disposed parallel to joint surface **34***a* of the first electrical conductor **34** and side by side with the first semiconductor element **38** with a gap therebetween in the longitudinal direction of the first electrical conductor **34**. One electrode of the second semiconductor element **40** is joined to joint surface **34***a* of the first electrical conductor **34** with a second connecting body, for example, a rectangular solder sheet **42***b*, therebetween.

Thus, the first and second semiconductor elements **38** and **40** are disposed parallel to joint surface **34***a* of the first electrical conductor **34** and perpendicular to bottom surface **34***b* of the first electrical conductor.

Further, a fifth connecting body, for example, a rectangular solder sheet **42***e*, is provided on joint surface **34***a* of the first electrical conductor **34** and located beside the first semiconductor element **38**.

A first convex electrical conductor **44***a* for positioning is joined to the other electrode of the first semiconductor element **38** with a third connecting body, for example, a rectangular solder sheet **42***c*, therebetween. The first convex electrical conductor **44***a* is made of, for example, copper and integrally comprises a flat cuboid main body and a flat cuboid projection **45***a* smaller than the main body and projecting from one principal surface of the main body. The flat principal surface side of the main body of the first convex electrical conductor **44***a* is joined electrically and mechanically to the electrode of the first semiconductor element **38** by solder sheet **42***c*.

A second convex electrical conductor **44***b* for positioning is joined to the other electrode of the second semiconductor element **40** with a fourth connecting body, for example, a rectangular solder sheet **42***f*, therebetween. The second convex electrical conductor **44***b* is made of, for example, copper and integrally comprises a flat cuboid main body and a flat cuboid projection **45***b* smaller than the main body and projecting from the one principal surface of the main body. The flat principal surface side of the main body of the second convex electrical conductor **44***b* is joined electrically and mechanically to the electrode of the second semiconductor element **40** by solder sheet **42***f*.

The first and second convex electrical conductors **44***a* and **44***b* need not always be separate parts, and their main bodies may be integrally formed so that the two projections can be provided on a common main body.

As shown in FIGS. **4** to **9**, each semiconductor module **16** comprises first and second power terminals **46***a* and **46***b*, which are each formed of a lead frame or electrically conductive metal plate (described later), junction (emitter plate) **48** continuous with the second power terminal, and a plurality (for example, five) of signal terminals **50**.

The first power terminal **46***a* is an independent structure, the proximal end portion of which is joined to joint surface **34***a* of the first electrical conductor **34** by solder sheet **42***e*. The first power terminal **46***a* projects outwardly relative to the module from one longitudinal end of the first electrical conductor **34**, and its contact portion **47***a* is bent at right angles toward the first electrical conductor **34** and opposed substantially parallel to one end surface of the module.

The proximal end portion of the second power terminal **46***b* is connected to the junction (emitter plate) **48**. Further, the second power terminal **46***b* projects outwardly relative to the module from the other longitudinal end of the first electrical conductor **34**, and its contact portion **47***b* is bent at right angles toward the first electrical conductor **34** and opposed substantially parallel to the other end surface of the module.

The junction (emitter plate) **48** is an elongated rectangular plate. First and second openings **51***a* and **51***b* for positioning are formed side by side in the junction **48**. The first opening **51***a* has such a size that projection **45***a* of the first convex electrical conductor **44***a* can be fitted therein and is smaller than the main body of the conductor **44***a*. Likewise, the second opening **51***b* has such a size that projection **45***b* of the second convex electrical conductor **44***b* can be fitted therein and is smaller than the main body of the conductor **44***b*. The surface of the junction **48** on the side of the second electrical conductor **36** is formed with a shallow rectangular recess **56**, which covers an area including the first and second openings **51***a* and **51***b*. Further, the junction **48** integrally comprises three supporting projections projecting upwardly from its upper edge. One of the signal terminals **50** extends upwardly from the central supporting projection. Specifically, an emitter branch **50***a*, one of the five signal terminals **50**, diverges from the junction (emitter plate) **48** and is located substantially parallel to the other signal terminals **50**.

The junction **48** and second power terminal **46***b* are joined to the first and second convex electrical conductors **44***a* and **44***b* with projections **45***a* and **45***b* of the conductors **44***a* and **44***b* in engagement with the first and second openings **51***a* and **51***b*, respectively.

Further, the junction **48** and projections **45***a* and **45***b* of the first and second convex electrical conductors **44***a* and **44***b* are joined electrically and mechanically to joint surface **36***a* of the second electrical conductor **36** by a sixth connecting body, for example, a rectangular solder sheet **42***d*, in the recess **56** of the junction **48**. Thus, the junction **48**, first and second convex electrical conductors **44***a* and **44***b*, and second electrical conductor **36** are joined to one another by solder sheet **42***d*.

In this way, the electrodes of the first and second semiconductor elements **38** and **40** are electrically joined to the second electrical conductor **36** through the first and second convex electrical conductors **44***a* and **44***b*. The semiconductor elements **38** and **40** are interposed between the first and second electrical conductors **34** and **36** and disposed parallel to joint surfaces **34***a* and **36***a* and perpendicular to bottom surfaces **34***b* and **36***b* of the conductors **34** and **36**.

The signal terminals **50** project upwardly from the module and extend parallel to joint surface **34***a* of the first electrical conductor **34**. The respective proximal ends of the remaining four signal terminals **50** are connected to the connecting terminals **38***a* of the first semiconductor element **38** by bonding wires **53**, individually. FIG. **45** shows an equivalent circuit of the semiconductor module **16**. As shown in FIGS. **6**, **7** and **45**, the signal terminals **50** comprise the emitter branch (collector-emitter voltage monitor terminal or branch signal terminal) **50***a*, a current (emitter sense current) monitor terminal **50***b*, a gate (gate-emitter voltage) terminal **50***c*, and chip temperature monitor terminals **50***d* and **50***e*. The emitter branch **50***a* diverges from or conducts to the junction (emitter plate) **48**. The respective proximal ends of the signal terminals **50***b* to **50***e* and their corresponding connecting terminals **38***a* of the first semiconductor element **38** are connected to one another by the bonding wires (lead wires) **53**. The first semiconductor element **38** is connected to the first and second power terminals **46***a* and **46***b* through the first and second electrical conductors **34** and **36**, respectively. Likewise, the second semiconductor element **40** is connected to the power terminals **46***a* and **46***b* through the electrical conductors **34** and **36**, respectively.

As shown in FIGS. **4** to **8** and FIGS. **10** to **12**, each semiconductor module **16** comprises an envelope, for example, a molded resin body (insulator) **52**, which covers and seals the constituent members described above. The molded resin body **52** is a substantially rectangular block structure comprising two parallel lateral surfaces **52***a* and **52***b*, flat bottom surface **52***c*, top surface **52***d*, and two end surfaces **52***e*. Lateral surfaces **52***a* and **52***b* are located parallel to joint surfaces **34***a* and **36***a* of the first and second electrical conductors **34** and **36**. Bottom surface **52***c* extends perpendicular to lateral surfaces **52***a* and **52***b*. The top surface **52***d* is opposed to bottom surface **52***c*. The end surfaces **52***e* are located individually at the longitudinally opposite ends of the molded resin body **52**. Bottom surface **52***c* is ground flat, and the respective bottom surfaces **34***b* and **36***b* of the first and second electrical conductors **34** and **36** are exposed in bottom surface **52***c* and located flush with bottom surface **52***c*.

The molded resin body **52** has a parting line **54** formed during forming-die cutting. This parting line **54** is located within a plane containing the junction **48** of the lead frame and the first and second power terminals **46***a* and **46***b* and remains along the top surface **52***d* and opposite end surfaces **52***e* of the molded resin body **52**. Further, the parting line **54** is offset from the center of the molded resin body **52** in a thickness direction W (FIG. **11**) toward lateral surface **52***b*.

That part of the top surface **52***d* of the molded resin body **52** which is located between the parting line **54** and lateral surface **52***a* is slightly inclined toward bottom surface **52***c* as it extends from the parting line **54** toward lateral surface **52***a*. That part between the parting line **54** and lateral surface **52***b* is slightly inclined toward bottom surface **52***c* as it extends from the parting line **54** toward lateral surface **52***b*.

That part of each end surface **52***e* of the molded resin body **52** which is located between the parting line **54** and lateral surface **52***a* is slightly inclined toward the other end surface as it extends from the parting line **54** toward lateral surface **52***a*. That part between the parting line **54** and lateral surface **52***b* is slightly inclined toward the other end surface as it extends from the parting line **54** toward lateral surface **52***b*.

As shown in FIGS. **4** to **8** and FIGS. **10** to **12**, the first power terminal **46***a* projects longitudinally outwardly relative to the molded resin body **52** from its one end surface **52***e* in the position of the parting line **54**. Further, contact portion **47***a* of the first power terminal is bent at right angles toward lateral surface **52***a* and spacedly opposed to the end surface **52***e* of the molded resin body **52**. As contact portion **47***a* is bent, moreover, it is located in the center of the molded resin body **52** in the thickness direction W thereof.

The second power terminal **46***b* projects longitudinally outwardly relative to the molded resin body **52** from its other end surface **52***e* in the position of the parting line **54**. Further, contact portion **47***b* of the second power terminal is bent at right angles toward lateral surface **52***a* and spacedly opposed to the end surface **52***e* of the molded resin body **52**. As contact portion **47***b* is bent, moreover, it is located in the center of the molded resin body **52** in the thickness direction W thereof.

Each of the five signal terminals **50** is in the form of an elongated rod projecting upwardly from the top surface **52***d* of the molded resin body **52** in the position of the parting line **54**. The five signal terminals **50** extend parallel to one another. Each signal terminal **50** is bent at two longitudinally spaced points, and its extending end portion **53***a* is located in the center of the molded resin body **52** in the thickness direction W. As shown in FIG. **11**, moreover, the five signal terminals **50** and first and second power terminals **46***a* and **46***b* are disposed bilaterally symmetrically with respect to a center line C that is located in the longitudinal center of the molded resin body **52**. An electrically conductive film (not shown) is formed on at least the outer surface of the end portion **53***a* of each signal terminal **50**.

As shown in FIGS. **1**, **10** and **12**, the semiconductor modules **16** constructed in this manner are disposed in the installation space portion **22** of the support frame **14** so that their respective bottom surfaces **52***c* are set on the heat receiving surface **18***a* of the cooler **12** with an insulating sheet **55** therebetween. Thus, the first and second electrical conductors **34** and **36** are thermally connected to the cooler **12** so that heat produced in the first and second semiconductor elements **38** and **40** can be released to the cooler **12** through the electrical conductors **34** and **36**. Contact portions **47***a* and **47***b* of the first and second power terminals **46***a* and **46***b* of each semiconductor module **16** contact their corresponding connecting terminals **24** of the bus bars **26** and are electrically connected to the bus bars **26**. Further, the signal terminals **50** of each semiconductor module **16** project upwardly.

Each two adjacent ones of the plurality of semiconductor modules **16** arranged in a row are disposed in such a manner that the lateral surfaces of their respective molded resin bodies **52** adjacently face or contact one another. One of each two adjacent semiconductor modules **16** may be oriented inversely or at 180° to the other. The first and second power terminals **46***a* and **46***b* of the semiconductor modules are configured to reliably engage with the connecting terminals **24** of the bus bars **26** without regard to the orientation. Regardless of the orientation, also in this case, the signal terminals **50** of each semiconductor module **16** are located in the central part of the molded resin body **52** in the thickness direction and disposed in predetermined positions relative to the control circuit board **32**.

As the control circuit board **32** is set on the semiconductor modules **16**, as shown in FIG. **3**, the end portions of the signal terminals **50** of each semiconductor module **16** are passed through through-holes in the control circuit board **32** and electrically connected to the control circuit board by solder (not shown) or the like.

The following is a description of a method of manufacturing the semiconductor modules **16** that constitute the semiconductor power converter described above. FIGS. **13** to **44** are perspective and sectional views individually showing processes of manufacturing the semiconductor modules.

First, as shown in FIGS. **13** and **14**, a first fixing jig **60** of, for example, SUS is prepared, and the first electrical conductor **34** is fitted and positioned in a positioning recess of the first fixing jig. As this is done, the first electrical conductor **34** is loaded into the first fixing jig **60** so that its joint surface **34***a* faces upwardly. The first fixing jig **60** is in the form of a rectangular box comprising a rectangular bottom wall **60***a* and a peripheral wall **60***b* set up along the peripheral edge of the of the bottom wall. The bottom wall **60***a* is formed with a rectangular positioning recess **60***c* of a size corresponding to the first electrical conductor **34**. A through-hole **60***g* is formed in the center of the positioning recess **60***c*. In mold release, an ejector pin is passed through the through-hole **60***g* and pushes up and removes the first electrical conductor **34** from the first fixing jig **60**. Further, the peripheral wall **60***b* is formed with two recesses **60***d* that are located on the longitudinally opposite sides of the positioning recess **60***c*. Two positioning pins **60***e* are set up at the bottom of each recess **60***d*. Further, the first fixing jig **60** comprises four positioning pins **60***f* set up at the four corners of the peripheral wall **60***b*.

Then, as shown in FIGS. **15** and **16**, a split jig **62** of, for example, SUS in the form of an elongated rectangular plate is placed on joint surface **34***a* of the first electrical conductor **34** in such a manner that its opposite end portions are disposed within the recesses **60***d* of the first fixing jig **60**. Further, positioning pins **60***e* of the first fixing jig **60** are inserted individually into positioning holes in the end portions of the split jig **62**, whereupon the split jig **62** is positioned relative to the first electrical conductor **34**.

The split jig **62** comprises rectangular first, second, and third openings **63***a*, **63***b* and **63***c* configured to position the first and second semiconductor elements and the proximal end portion of the first power terminal **46***a*, respectively. These openings are located above joint surface **34***a*. The split jig **62** is divided into two parts, first and second segments **62***a* and **62***bs*, along a center line that passes through the first to third openings. Thus, the first and second segments **62***a* and **62***bs* can be independently attached to and detached from the first fixing jig **60**.

Subsequently, as shown in FIGS. **17** and **18**, the first connecting body or rectangular solder sheet **42***a* is placed on joint surface **34***a* of the first electrical conductor **34** in the first opening **63***a* of the split jig **62**. Further, the second connecting body or rectangular solder sheet **42***b* is placed on joint surface **34***a* of the first electrical conductor **34** in the second opening **63***b* of the split jig **62**. Solder sheets **42***a* and **42***b* and a plurality of solder sheets (described later) used each contain a plurality (for example, three or more) of more particles. The inclusion of particles of a predetermined diameter keeps the height of the junction from becoming smaller than the particle diameter even after solder is melted and solidified. The particles are made of a material higher in melting temperature than the solder. Further, the particles require sufficient hardness to avoid significant change attributable to the second electrical conductor and a counterweight, and should have a diameter equal to a designed joint height.

Then, as shown in FIGS. **19** and **20**, the first semiconductor element **38** is placed on solder sheet **42***a* in the first opening **63***a* of the split jig **62**. When this is done, the first semiconductor element **38** is placed on joint surface **34***a* of the first electrical conductor **34** in a parallel relationship so that its one electrode is located on solder sheet **42***a*. At the same time, the first semiconductor element **38** is disposed in the first opening **63***a* and positioned relative to the first electrical conductor **34** by the split jig **62**.

The second semiconductor element **40** is placed on solder sheet **42***b* in the second opening **63***b* of the split jig **62**. When this is done, the second semiconductor element **40** is placed on joint surface **34***a* of the first electrical conductor **34** in a parallel relationship so that its one electrode is located on solder sheet **42***b*. At the same time, the second semiconductor element **40** is disposed in the second opening **63***b* and positioned relative to the first electrical conductor **34**.

Subsequently, as shown in FIGS. **21** and **22**, the third connecting body or rectangular solder sheet **42***c* is placed on the electrode of the first semiconductor element **38** in the first opening **63***a* of the split jig **62**. Further, the fourth connecting body or rectangular solder sheet **42***f* is placed on the electrode of the second semiconductor element **40** in the second opening **63***b* of the split jig **62**. Furthermore, the fifth connecting body or rectangular solder sheet **42***e* is placed on joint surface **34***a* of the first electrical conductor **34** in the third opening **63***c* of the split jig **62**. Solder sheets **42***c*, **42***f* and **42***e* used each contain a plurality (for example, three or more) of more particles of a predetermined diameter.

Then, as shown in FIGS. **23** and **24**, the first convex electrical conductor **44***a* is placed on solder sheet **42***c* in the first opening **63***a* of the split jig **62**. When this is done, the first convex electrical conductor **44***a* is placed so that the flat principal surface side of its main body is located above solder sheet **42***c*, and the upper part of the main body and projection **45***a* project upwardly beyond the surface of the split jig **62** from the first opening **63***a*.

The second convex electrical conductor **44***b* is placed on solder sheet **42***f* in the second opening **63***b* of the split jig **62**. When this is done, the second convex electrical conductor **44***b* is placed so that the flat principal surface side of its main body is located above solder sheet **42***f*, and the upper part of the main body and projection **45***b* project upwardly beyond the surface of the split jig **62** from the second opening **63***b*. The first and second convex electrical conductors **44***a* and **44***b* are formed by stamping a metal block.

Subsequently, a lead frame **70** formed of an electrically conductive metal plate is placed on the first fixing jig **60** and first and second convex electrical conductors **44***a* and **44***b*. As shown in FIG. **25**, the lead frame **70** integrally comprises a rectangular frame body **70***a*, the first and second power terminals **46***a* and **46***b*, the rectangular junction **48**, the five signal terminals **50**, connecting portions (tie-bars) **71**, and a plurality of elongated connecting portions. The first power terminal **46***a* extends inwardly from one side portion of the frame body. The second power terminal **46***b* extends inwardly from the other side portion of the frame body. The junction **48** extends from the second power terminal toward the first power terminal. The signal terminals **50** extend inwardly from the other side portion of the frame body. The tie-bars **71** connect the five signal terminals **50** to one another and also to the frame body. The elongated connecting portions connect the junction **48** and frame body **70***a*. Of the signal terminals **50**, the emitter branch (collector-emitter voltage monitor terminal) **50***a* extends from the junction (emitter plate) **48** and conducts to it. The other signal terminals, including the current monitor terminal **50***b*, gate terminal **50***c*, and chip temperature monitor terminals **50***d* and **50***e*, extend inwardly from the frame body **70***a* and are separated from the junction **48**.

The junction (emitter plate) **48** is formed with the rectangular first and second openings **51***a* and **51***b* arranged side by side. The surface of the junction **48** on the side of the second electrical conductor **36** is formed with the shallow rectangular recess **56**, which covers the area including the first and second openings **51***a* and **51***b*. Further, the proximal end portion of the first power terminal **46***a* is downwardly bent a step below by pressing or the like so that it is offset from the junction **48** toward the first electrical conductor **34** by a margin corresponding to the respective thicknesses of the first semiconductor element **38** and first convex electrical conductor **44***a*.

Furthermore, positioning holes **70***b* are formed individually at the four corners of the frame body **70***a*.

As shown in FIGS. **26** and **27**, the lead frame **70** is disposed on the peripheral wall **60***b* of the first fixing jig **60**, and the four positioning pins **60***f* of the first fixing jig **60** are passed individually through the positioning holes **70***b* of the lead frame **70**, whereupon the lead frame **70** is positioned relative to the first fixing jig **60**. The junction **48** of the lead frame **70** is placed on the first and second convex electrical conductors **44***a* and **44***b*. As this is done, the respective upper surfaces of the main bodies of the convex electrical conductors **44***a* and **44***b* contact the lower surface of the junction **48**, and moreover, projections **45***a* and **45***b* are fitted in the first and second openings **51***a* and **51***b*, respectively, of the junction **48**. In this way, the convex electrical conductors **44***a* and **44***b* are positioned relative to the junction **48**. Further, projections **45***a* and **45***b* are exposed in the surface of the junction **48**, especially in the bottom surface of the recess **56**. On the other hand, the proximal end portion of the first power terminal **46***a* is placed on solder sheet **42***e* on joint surface **34***a*.

Subsequently, as shown in FIGS. **28** and **29**, the elongated rectangular solder sheet **42***d* as the sixth connecting body is placed in the recess **56** of the junction **48**. Solder sheet **42***d* is placed on the junction **48** and projections **45***a* and **45***b* of the first and second convex electrical conductors **44***a* and **44***b*.

As shown in FIGS. **30** and **31**, a second fixing jig **80** is placed overlapping the first fixing jig **60** and lead frame **70**. The second fixing jig **80** is a rectangular plate of, for example, SUS substantially as large as the first fixing jig **60**, and comprises a rectangular positioning opening **80***a* in which the second electrical conductor can be fitted. The second fixing jig **80** is placed on the lead frame **70** in such a manner that it is positioned relative to the first fixing jig **60** with positioning pins **60***f* of the first fixing jig **60** engaging with engagement recesses at the four corners of the bottom surface. Thus, the second fixing jig **80** presses down and holds the lead frame **70** in a predetermined position from above. Further, the positioning opening **80***a* of the second fixing jig **80** is located opposite the junction **48** and solder sheet **42***d*.

Subsequently, as shown in FIGS. **32** and **33**, the second electrical conductor **36** is fitted in the positioning opening **80***a* of the second fixing jig **80**, placed on solder sheet **42***d* and junction **48**, and positioned by the second fixing jig **80**. When this is done, the second electrical conductor **36** is oriented so that its joint surface **36***a* contacts solder sheet **42***d*.

Then, as shown in FIGS. **34** and **35**, a prismatic counterweight **82** is fitted in the positioning opening **80***a* of the second fixing jig **80** and mounted on the second electrical conductor **36**. The counterweight **82** serves to press the above-described members in the direction of lamination and secure their positions. The weight of the counterweight **82** is selected so that the height of the joint portion is substantially equivalent to the size of the particles in the solder.

The constituent members and the first and second fixing jigs **60** and **80** thus laminated and positioned are heated for a predetermined time in, for example, a reflow oven, whereby solder sheets **42***a* to **42***f* are collectively melted. Thereafter, the solder sheets are cooled so that the solder is solidified, whereupon the constituent members are joined together. In the solder joining, solder sheet **42***d* is disposed in the recess **56** of the junction **48**, so that the solder does not flows out of the recess **56** as it melts, and the constituent members can be joined in predetermined positions. As solder sheet **42***d* melts, moreover, it joins the junction **48**, projections **45***a* and **45***b* of the first and second convex electrical conductors, and second electrical conductor **36** to one another.

After the solder sheets are melted and solidified in this manner, the counterweight **82**, first and second fixing jigs **60** and **80**, and split jig **62** are removed from the joined constituent members and lead frame **70**, as shown in FIG. **36**. Subsequently, as shown in FIG. **37**, the joined constituent members and lead frame **70** are subjected to visual inspections. These inspections are conducted to see:

(A) if the semiconductor elements are not reached by the solder that joins the second electrical conductor **36** and junction **48** and projects from between them;

(B) if the second electrical conductor **36** and first power terminal **46***a* are in contact with each other;

(C) if there are no voids between the first electrical conductor **34** and first power terminal **46***a;*

(D) if the connecting terminals (pads) **38***a* of the first semiconductor element **38** are not reached by the solder that joins the first and second convex electrical conductors **44***a* and **44***b* and first and second semiconductor elements **38** and **40** and projects from between them; and

(E) if a wire bonding area is secured.

Subsequently, as shown in FIG. **38**, the respective proximal ends of the current monitor terminal **50***b*, gate terminal **50***c*, and chip temperature monitor terminals **50***d* and **50***e*, out of the signal terminals **50**, are connected to their corresponding connecting terminals **38***a* of the first semiconductor element **38** by the bonding wires **53**. After the wire bonding, as shown in FIG. **9**, a visual inspection is conducted to see (F) if there are no wire voids, if the wire loop shape is not collapsed, etc.

Then, as shown in FIG. **40**, all the constituent members except the respective distal end portions of the first and second power terminals **46***a* and **46***b* and signal terminals **50** are covered and sealed by an insulating material, such as a resin. Thereupon, the substantially cuboid molded resin body (envelope) **52** is molded. This molded resin body **52** is molded by disposing the aforementioned joined laminate in a forming die and injecting a synthetic resin into the die. The forming die is released on either side of the lead frame **70**, whereupon the parting line **54** flush with the lead frame **70** is formed on the molded resin body **52**.

Subsequently, as shown in FIGS. **41** and **42**, the lead frame **70** is cut in predetermined positions and separated from the molded resin body **52**, and the five signal terminals **50** and first and second power terminals **46***a* and **46***b* are cut down. The cutting positions are indicated by broken lines in FIG. **41**.

As shown in FIG. **43**, the bottom surface of the molded resin body **52** is ground to form the flat bottom surface **52***c* perpendicular to lateral surface **52***b* of the molded resin body **52**, and the respective bottom surfaces **34***b* and **36***b* of the first and second electrical conductors **34** and **36** are exposed in bottom surface **52***c* of the molded resin body **52**. Bottom surfaces **34***b* and **36***b* of the electrical conductors **34** and **36** and bottom surface **52***c* of the molded resin body **52** are formed so that they extend perpendicular to the first and second semiconductor elements **38** and **40**.

Thereafter, as shown in FIGS. **41** and **44**, contact portions **47***a* and **47***b* of the first and second power terminals **46***a* and **46***b* are bent at a right angle, and each signal terminal **50** is bend-formed in two positions. The bending positions are indicated by two-dot chain lines in FIG. **41**. Finally, the electrically conductive film is formed on the surface of each signal terminal **50**.

The semiconductor module **16** of the power converter is completed by the processes described above.

According to the semiconductor power converter and its manufacturing method arranged in this manner, the lead frame (junction) is provided comprising the convex electrical conductors and the openings in which the projections of the convex electrical conductors are fitted, whereby the convex electrical conductors can be prevented from becoming misaligned. Further, the first and second convex electrical conductors, junction of the lead frame, and second electrical conductor can be joined by the common fifth connecting body (solder sheet), so that the connecting bodies and positions for joint soundness checks can be reduced in number.

The lead frame integrally comprises the power terminals and signal terminals and further comprises the openings for positioning the convex electrical conductors and the recesses for holding the connecting bodies. The depth of the recesses should not be greater than the joint height of the melted and solidified connecting bodies (solder sheets). The parts count can be reduced by forming the power terminals and signal terminals into an integral part (lead frame). Also, if this is done, the accuracy of the mounting positions of the power terminals and signal terminals is higher and the dimensional variation of finished products is less than in the case where the power terminals and signal terminals are handled as separate parts.

As the solder that forms the connecting bodies contains a plurality of particles, it can be controlled so that the height of the joint portion should not become smaller than the partial diameter. Thus, variation of the height of the joint portion can be reduced to improve the assembly accuracy. As the counterweight is mounted on the second electrical conductor at the time of joining, moreover, the second electrical conductor is prevented from being lifted by the surface tension of the solder, so that variation of the height of the joint portion is reduced. At the same time, the constituent parts being joined can be prevented from becoming misaligned by applying a load to the parts by means of the counterweight.

By using the split jig to position the first and second semiconductor elements during the manufacture of the semiconductor module, the jig can be easily removed even after the connecting body (solder) is solidified. If the jig is made of SUS, moreover, solder cannot easily adhere to it due to the properties of the material. The coefficient of linear expansion of SUS304 is 17.3 ppm/° C., which is approximate to that of copper, 16.7 ppm/° C. If the jig is made of SUS, therefore, it can be prevented from biting a part and becoming unremovable from it due to thermal expansion or contraction, which may otherwise be caused by a temperature difference as the solder melts and solidifies.

Thus, there may be provided a semiconductor power converter, capable of being downsized and improved in reliability and high in product yield and finished-product dimensional stability, and a method of manufacturing the same.

The following is a description of a method of manufacturing a semiconductor power converter according to an alternative embodiment. In the description of this alternative embodiment to follow, like reference numbers are used to designate the same parts as those of the foregoing first embodiment, and a detailed description thereof is omitted. The following is a detailed description focused on different parts.

Second Embodiment

According to a second embodiment, as in the first embodiment described above, various constituent members of a semiconductor module **16** are joined together in the processes shown in FIGS. **13** to **40**. Thereafter, most of the constituent members including semiconductor elements are covered and sealed by a molded resin body (envelope) **52**, as shown in

FIG. **46**. Signal terminals **50** and first and second power terminals **46***a* and **46***b* extend outwardly from the molded resin body **52**.

Then, as shown in FIGS. **47** to **49**, a lead frame **70** is cut in predetermined positions and separated from the molded resin body **52**. The cutting positions are indicated by broken lines in FIG. **47**. In the present embodiment, all other parts of the lead frame **70** than a junction **48**, the first and second power terminals **46***a* and **46***b*, the signal terminals **50**, and connecting portions (tie-bars) **71** connecting the signal terminals are cut off. Specifically, five signal terminals **50***a*, **50***b*, **50***c*, **50***d* and **50***e* are cut down from the lead frame **70** in such a manner that they are connected to one another by the connecting portions **71**.

Subsequently, as shown in FIG. **50**, the bottom surface of the molded resin body **52** is ground, with the five signal terminals **50***a* to **50***e* kept connected by the connecting portions **71**, to form a flat bottom surface **52***c* perpendicular to a lateral surface **52***b* of the molded resin body **52**. Also, respective bottom surfaces **34***b* and **36***b* of first and second electrical conductors **34** and **36** are exposed in bottom surface **52***c* of the molded resin body **52**. Bottom surfaces **34***b* and **36***b* of the electrical conductors **34** and **36** and bottom surface **52***c* of the molded resin body **52** are formed so that they extend perpendicular to first and second semiconductor elements **38** and **40**.

Thereafter, as shown in FIG. **4**, the tie-bars **71** that connect the five signal terminals **50** are cut off, contact portions **47***a* and **47***b* of the first and second power terminals **46***a* and **46***b* are bent at a right angle, and each signal terminal **50** is bend-formed in two positions. The bending positions are indicated by two-dot chain lines in FIG. **47**. Finally, an electrically conductive film is formed on the surface of each signal terminal **50**.

The semiconductor module **16** of a power converter is completed by the processes described above. The tie-bars **71** may be cut off after the signal terminals **50** are bend-formed or after the electrically conductive film is formed. In short, the cutting should only be performed after the bottom surface of the molded resin body is ground and before a continuity test is started.

In many cases, a grinder is not entirely grounded in the process of grinding the bottom surface of the molded resin body **52** for exposure. During transportation, moreover, static electricity may possibly be produced by a systematic or human cause. According to the manufacturing method of the second embodiment, therefore, the connecting portions **71** are left in the process of cutting the lead frame **70** so that they can be cut after the process of grinding the bottom surface of the molded resin body. In this way, the semiconductor element can be protected from electrostatic breakdown. The connecting portions **71** are cut in a lead foaming process. Since the forming die is grounded, however, static electricity is released from the die to the ground.

If static electricity is applied to connecting terminals **38***a* of the semiconductor element with the connecting terminals **38***a* and signal terminals **50** connected by bonding wires **53** and with the tie-bars cut, there is a possibility of the semiconductor element being broken. More specifically, if the signal terminals are subjected to a high potential by the static electricity such that a potential difference from the second electrical conductor **36** is produced, a voltage higher than the withstand voltage is applied to and breaks the intervening semiconductor element. In order to avoid such electrostatic breakdown, it is effective to short-circuit the signal terminals **50** including the emitter branch **50***a*, thereby providing a channel in which high voltage is not applied to the semiconductor element and discharging the static electricity, as in the present embodiment. Thus, according to the second embodiment, there may be provided a method of manufacturing a semiconductor power converter, in which the semiconductor element can be reliably prevented from being damaged by static electricity, and the product yield and reliability can be improved.

The same functions and effects as those of the first embodiment described above can also be obtained from the second embodiment.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

For example, the sizes, shapes, etc., of the constituent members of the power converter are not limited to those of the embodiments described above and may be variously changed depending on the design.

What is claimed is:

1. A method of manufacturing a semiconductor power converter, comprising:

mounting a first connecting body and a second connecting body on a first joint surface of a first electrical conductor;

mounting a plate-shaped first semiconductor element, which comprises different electrodes on the obverse and reverse surfaces thereof, on the first connecting body so that one of the electrodes contacts the first connecting body;

mounting a plate-shaped second semiconductor element, which comprises different electrodes on the obverse and reverse surfaces thereof, on the second connecting body so that one of the electrodes contacts the second connecting body;

mounting a third connecting body on the other electrode of the first semiconductor element;

mounting a fourth connecting body on the other electrode of the second semiconductor element;

mounting a fifth connecting body on the first joint surface of the first electrical conductor;

mounting a first convex electrical conductor comprising a projection on the third connecting body;

mounting a second convex electrical conductor comprising a projection on the fourth connecting body;

mounting on the fifth connecting body a first power terminal of a lead frame, which comprises a plate-shaped junction comprising a first opening engageable with the projection of the first convex electrical conductor and a second opening engageable with the projection of the second convex electrical conductor, the first power terminal, a second power terminal, and a plurality of signal terminals, in such a manner that the projections of the first and second convex electrical conductors are fitted in the first and second openings of the lead frame, respectively;

mounting a sixth connecting body overlapping the projections of the first and second convex electrical conductors on the junction of the lead frame;

mounting a second electrical conductor comprising a second joint surface on the sixth connecting body so that the second joint surface faces the first joint surface of the first electrical conductor;

collectively melting and then solidifying the first to sixth connecting bodies and joining the first electrical conductor, the first and second semiconductor elements, the first and second convex electrical conductors, the first power terminal, the junction, and the second electrical conductor to one another;

connecting the signal terminals and connecting terminals of the first semiconductor element by means of lead wires;

forming an envelope by covering and sealing respective proximal end portions of the first and second power terminals, proximal end portions of the signal terminals, and the other constituent members with an insulating material;

cutting off other parts of the lead frame than the junction, the first and second power terminals, and the signal terminals;

grinding the envelope to form a bottom surface which extends perpendicular to the first and second semiconductor elements and in which respective bottom surfaces of the first and second electrical conductors are exposed; and

bend-forming the first and second power terminals and the signal terminals.

2. The method of manufacturing a semiconductor power converter of claim **1**, wherein the first convex electrical conductor, the junction of the lead frame, and the second joint surface of the second electrical conductor are joined to one another by the sixth connecting body.

3. The method of manufacturing a semiconductor power converter of claim **2**, wherein the junction of the lead frame is formed with a recess in an area including the first and second openings, and the sixth connecting body is mounted in the recess.

4. The method of manufacturing a semiconductor power converter of claim **1**, wherein solder containing a plurality of particles is used for the first to sixth connecting bodies.

5. A method of manufacturing a semiconductor power converter, comprising:

mounting a first connecting body and a second connecting body on a first joint surface of a first electrical conductor;

mounting a plate-shaped first semiconductor element, which comprises different electrodes on the obverse and reverse surfaces thereof, on the first connecting body so that one of the electrodes contacts the first connecting body;

mounting a plate-shaped second semiconductor element, which comprises different electrodes on the obverse and reverse surfaces thereof, on the second connecting body so that one of the electrodes contacts the second connecting body;

mounting a third connecting body on the other electrode of the first semiconductor element;

mounting a fourth connecting body on the other electrode of the second semiconductor element;

mounting a fifth connecting body on the first joint surface of the first electrical conductor;

mounting a first convex electrical conductor comprising a projection on the third connecting body;

mounting a second convex electrical conductor comprising a projection on the fourth connecting body;

mounting on the fifth connecting body a first power terminal of a lead frame, which comprises a plate-shaped junction comprising a first opening engageable with the projection of the first convex electrical conductor and a second opening engageable with the projection of the second convex electrical conductor, the first power terminal, a second power terminal, a branch signal terminal diverging from the junction and a plurality of other signal terminals, and connecting portions connecting the branch signal terminal and the signal terminals to one another, in such a manner that the projections of the first and second convex electrical conductors are fitted in the first and second openings of the lead frame, respectively;

mounting a sixth connecting body overlapping the projections of the first and second convex electrical conductors on the junction of the lead frame;

mounting a second electrical conductor comprising a second joint surface on the sixth connecting body so that the second joint surface faces the first joint surface of the first electrical conductor;

collectively melting and then solidifying the first to sixth connecting bodies and joining the first electrical conductor, the first and second semiconductor elements, the first and second convex electrical conductors, the first power terminal, the junction, and the second electrical conductor to one another;

connecting the signal terminals and connecting terminals of the first semiconductor element by means of lead wires;

forming an envelope by covering and sealing respective proximal end portions of the first and second power terminals, proximal end portions of the signal terminals, and the other constituent members with an insulating material;

cutting off other parts of the lead frame than the junction, the first and second power terminals, the connecting portions, and the signal terminals;

grinding the envelope to form a bottom surface which extends perpendicular to the first and second semiconductor elements and in which respective bottom surfaces of the first and second electrical conductors are exposed; and

cutting off the connecting portions after the bottom surface is formed.

6. The method of manufacturing a semiconductor power converter of claim **5**, wherein the first convex electrical conductor, the junction of the lead frame, and the second joint surface of the second electrical conductor are joined to one another by the sixth connecting body.

7. The method of manufacturing a semiconductor power converter of claim **6**, wherein the junction of the lead frame is formed with a recess in an area including the first and second openings, and the sixth connecting body is mounted in the recess.

8. The method of manufacturing a semiconductor power converter of claim **5**, wherein solder containing a plurality of particles is used for the first to sixth connecting bodies.

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